IOWA STATE UNIVERSITY BULLETIN

The Statistical Laboratory Established 1933 Iowa State University

ANNUAL REPORT

July 1, 1964 to June 30, 1965

President W. R. Parks
Iowa State University of
Science and Technology
Ames, Iowa

Dear President Parks:

This is the annual report of the Statistical Laboratory at Iowa State University for the fiscal year July 1, 1964, through June 30, 1965. It reports on the research, consulting, teaching and operational work of the staff of the university statistical center.

The statistical center is composed of:

(1) The Statistical Laboratory, a research and service institute under the president's office;
(2) The teaching Department of Statistics in the College of Sciences and Humanities;
(3) The statistics department of the Agricultural and Home Economics Experiment Station;
(4) The statistics participant unit of the Sciences and Humanities Research Institute; and
(5) The research field office of the Statistical Standards Division, Statistical Reporting Service, United States Department of Agriculture, which is located in the Statistical Laboratory.

The staff members of the Statistical Laboratory work in cooperation with many institutions and departments of Iowa State University. This annual report is a review of these activities as well as a record of the activities carried on solely by the Statistical Laboratory.

Respectfully submitted on behalf
of the Statistical Laboratory staff,

T. A. Bancroft

T. A. Bancroft
Director, Statistical Laboratory;
Head, Department of Statistics;
Head, Statistics Department,
Agricultural and Home Economics
Experiment Station

THE STATISTICAL LABORATORY

Iowa State University

ANNUAL REPORT 1964-1965

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Ames, Iowa

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Personnel

The various components of the statistical center have a single director and share personnel. In fiscal terms, this means that a staff member's salary may be provided from several sources: the Department of Statistics in the College of Sciences and Humanities; the Statistical Laboratory, an institute under the president's office; a statistical project of the Iowa Agricultural and Home Economics Experiment Station or the Engineering Experiment Station; or a research contract by the Statistical Laboratory and the Sciences and Humanities Research Institute.

The Laboratory also has a number of research grants and contracts with federal agencies which provide funds for research for both staff and graduate students at all levels.

The members of the statistical center, including its affiliated fellows and graduate students, are listed here.

THE STATISTICAL LABORATORY STAFF FOR THE FISCAL YEAR 1964-65

Under the administrative direction of

James H. Hilton, D.Sc.....President of the University
Chalmer J. Roy, Ph.D.....Dean, College of Sciences and Humanities; Director, Sciences and Humanities Research Institute
Floyd Andre, Ph.D.....Dean, College of Agriculture; Director, Iowa Agricultural and Home Economics Experiment Station
Theodore A. Bancroft, Ph.D.....Director, Statistical Laboratory; Head, Department of Statistics; Head, Statistics Department, Iowa Agricultural and Home Economics Experiment Station

Professors

T. A. Bancroft
C. Philip Cox
Herbert T. David
David V. Huntsberger
Oscar Kempthorne – Distinguished Professor, College of Sciences and Humanities
George W. Ladd – joint appointment with Department of Economics and Sociology, fall quarter
George W. Snedecor – Professor Emeritus – in absentia
Norman V. Strand

Associate Professors

Om P. Aggarwal
Foster B. Cady
K. C. Chanda – visiting, through 1964 summer session
Wayne A. Fuller – on leave, fall through spring quarters, postdoctoral Fellow at Stanford University
William Hemmerle
Donald K. Hotchkiss
Akio Kudô – visiting, beginning winter quarter
C. C. Mosier – joint appointment with Computation Center
J. K. Sengupta – joint appointment with Department of Economics and Sociology – on leave
Leroy Wolins – joint appointment with Department of Psychology
George Zyskind

Assistant Professors

Carol Edwards Fuchs
Howard W. Jespersen – joint appointment with Computation Center
B. K. Kale – visiting
Edward Pollak
James R. Prescott – joint appointment with Department of Economics and Sociology
Fred Ramsey – fall quarter
Joseph Sedransk

Postdoctoral Fellow

Richard Oates

Instructors and Associates

Harold Baker
Rodney P. Basson
Edward J. Carney
Charles Cress
James S. DeGracie
Thomas Doerfler
Thomas C. Jetton
Glenn Richard Johnson
Dennis Lawing
Chang-Sheng Shih
Donald Soults
S. R. Srivastava – visiting, beginning first summer session
Richard D. Warren

Graduate Assistants

(The status of graduate students often changes. Students who have held the title of graduate assistant during the year are listed here.)

Joseph Atkinson
James Blinn
Leon Burmeister
Ralph Folsom
Edmund Fuller
Charles K. Graham
Irving Hall
Paul A. Johnson
Richard Lund
Mark Malone
Frank B. Martin
Richard Mensing
James Olin
Martin Rosenzweig
John Schlater
Jarilaos Stavrou
Ing-Tzer Wey
Janet Zrubek

Other Graduate Students

NIH Trainees:

Patricia Conn
James Gebert
John Johnson
Thomas Roseberry
Donna J. Ruhl
Charles Sampson
Steven Selvin
James Veale

NASA Fellows:

John Meyer
David Thomas

Affiliated Fellows:

Mohammad Aslam, AID, Census Bureau, Pakistan
Norman Beller, USDA Trainee
Carlos Brain, Government of Peru
Amiri Gamshadzahi, FAO, Iran
Lawrence Gould, NIH Trainee, Western Reserve University
Angel Martinez, Institute for Improvement of Sugar Production, Mexico
Esmat Nouri, Government of UAR
Carl Z. Roux, Union of South Africa
Ahmed Salem, Government of UAR
V. B. Solomon, Government of Ceylon
Tyler Sturdevant, USDA Trainee
Phrensi Svasti-Salee, Government of Thailand
Milton Weiss, Government of Canada
Herman Wiedenhofer, Government of Venezuela
Mia Mohammed Yusuf, AID, Census Bureau, Pakistan

Unaffiliated Students:

Geoffrey Boehm
Leroy Edward Carver
Ahmed El Mawaziny – in absentia
Burwell Gooch
Shun-jong Lee
Nancy Blackford Rowe
Nangnoi Suwanphant
Florence Tetreault – in absentia

Special Students

K. T. DeGraft-Johnson
Erol Farouk-Karaglou
Mario Murillo

Student Assistants (Undergraduate)

Richard Chapman
John DeMarle
Lee Jones
Ronald Mead
Paul Stachour
Ronald Wruck

General Office Staff

Margaret G. Kirwin, Administrative Assistant
Kathleen Ringgenberg, Accountant
Eleanor F. Bolton, Technical Writer-Editor – through fall quarter
Susan Alice Brown, Technical Writer-Editor – beginning fall quarter
Glenda Sampson, Secretary
Judith Donald, Secretary
Lucille McInerney, Secretary – fall and winter quarters
Avonelle Jacobson, Secretary, Teaching Group
Iveta Zeliadt, Secretary, Experimental Design Group

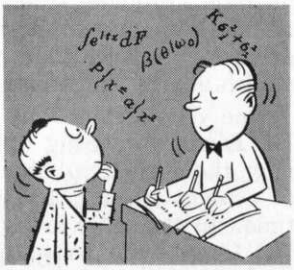
Numerical Analysis-Programming Group

Shirley Saveraid, Secretary
Mary Ann Carney, Technician
Gretchen Snowden, Technician

Survey Group

Anne Leicht, Secretary
Helen Ayres, Survey Supervisor
Marjorie Mason, Clerical Supervisor
Clerks:
Hazel Cook (Interviewer)
Ava Klopf
Mabel Matthews
Marie Ostermann
Lucile White
Anna B. Woodrow

Consulting and Joint Research



The staff members of the Statistical Laboratory, through their consulting activities, participate in research being conducted in many departments of the University. This work is made possible by the budgetary allowance of the Statistical Laboratory and the financial support provided to some staff members by the Agricultural and Home Economics Experiment Station and the Engineering Experiment Station.

Consulting problems vary, not only in the technical nature of the problem, but also in the amount of assistance needed by the investigator. Some problems may be fairly routine while others need modification in existing statistical methods and/or the development of new statistical theory and methodology. Often one important service performed by the consulting statistician is to encourage a research worker to examine his objectives carefully in view of his proposed experiment to ensure that it will answer his questions.

It is not possible to report here all of the consulting activities of the Statistical Laboratory staff. Some consulting is completed in a few minutes, other projects involve many hours over periods of weeks or months. Some staff members are budgeted to devote a great deal of their time to consulting activities while others are budgeted primarily on research projects or to fulfill teaching assignments.

Consulting may be done with individual students or staff members or with groups of persons concerned with a single project. Frequently two or more staff members will be consulted, independently or jointly, on a single project. The results usually appear in a thesis, a paper or a publication. Sometimes the staff member's contribution is such that he is listed as a paper's co-author.

Staff members who have part-time consulting assignments were asked to select the most interesting or most significant projects on which they consulted during the past year to report here. This gives an indication of the consulting activities being carried out through the Statistical Laboratory but is not meant as a complete record of the work of each staff member involved in consulting.

Consulting services are available for statistical design of experiments, statistical design of surveys, statistical analysis and interpretation of data, numerical analysis and programming of a statistical nature, and the development and extension of new statistical methods and techniques.

Consulting in the Behavioral Sciences

Dr. Leroy Wolins, who holds a joint appointment in statistics and psychology, is involved in much of the research in the behavioral sciences. Although he continues to consult with students and faculty in various departments, an increasing proportion of his consulting time is spent with psychology students and faculty. He consults with all graduate students in psychology, a number which has increased considerably with the inception of the doctoral program in this department.

One of the high points of Dr. Wolins' consulting activities this year, which is representative of his consulting services under the auspices of the Statistical Laboratory, involved a highly significant and credible 4-factor interaction.

Research being conducted by Dr. D. Bruce Gardner, Department of Child Development, suggests that young children when switched from judging the duration of visual stimuli to judging the duration of auditory stimuli, at first overestimate stimuli of long duration and underestimate stimuli of short duration. They become more accurate with practice.

When the problem is approached in reverse and the children are switched from judging the duration of auditory stimuli to judging the duration of visual stimuli, they at first underestimate stimuli of long duration and overestimate stimuli of short duration. Again they become more accurate with practice.

With older children such trend over trials which appeared suggested the opposite trend over trials.

On a similar project directed by Dr. Gardner, Professor C. Philip Cox and Donna Ruhl consulted on the planning and analyses of experiments on intra-sensory transfer. The analysis of covariance was not common in such studies and, introduced here with age as the covariate, it proved useful in providing evidence of intra-sensory transfer.

Miss Ruhl has been listed as co-author of the article reporting the results of the research. An abstract appears in the publications section of this annual report.

Richard Warren, who holds a joint appointment in statistics and sociology, has consulted with graduate students on problems involving design and analysis of investigations in sociology and other social sciences. The consulting with graduate students in sociology included assistance with their research designs and surveys, analysis of data, and the statistical aspects of their theses.

Dr. Carol Fuchs assisted an undergraduate major in economics to interpret the results of a survey on the distribution of income of families in a town in England, conducted under the auspices of SPAN.

The technique of multiple regression and correlation was used to predict expenditures on certain items such as food by using the husband's age, years of education, family size, wife's age, years of education, and similar variables.

A number of interesting results were obtained, such as the fact that the wife's years of education correlated positively with the amount of expenditures whereas the husband's did not.

Much of the research in home economics is done

with financial support of the Iowa Agricultural and Home Economics Experiment Station. Under Project 101 Dr. Foster Cady and Dr. Donald K. Hotchkiss consulted with a large number of research workers and faculty members. The varied nature of the home economics projects required several different statistical approaches.

Food technology research required frequent use of incomplete block designs or designs in which the higher order interactions were confounded with relatively homogeneous blocks. This type of study results when taste panel work is being done and the panel members are restricted in the number of samples they can taste in one setting. Dr. Hotchkiss provided assistance in the design and evaluation of these studies, which included the use of turkey, pork roasts and beef steaks. Oven capacity has been proved to be another factor which often determines block size in these studies.

The food technology group determined the acceptability of irridated pork and chicken in combination with non-irridated meat products, by using several student groups as a tasting panel. A Chi Square test was used to check the independence of numerous subclassifications of the students as compared to the scores they gave the meat products.

A long term study of the nutrition of older women was subjected to some preliminary statistical evaluation by Dr. Hotchkiss, using regression techniques. The project was designed to see how the age of the person and the change in technology affect the food eating habits. The evaluation is attempting to make maximum use of repeated study of the same individual at varying time periods. However, considerable changes in personnel result throughout the study.

In a foods and nutrition study investigating certain fat absorption characteristics in doughnuts, Dr. Cady used a 2^3 factorial with lecithin level, use of frying fat and type of baking powder as the variables.

Preliminary experiments were run to estimate variance components for the selection of the optimum number of replicates, doughnuts, samples and determinations. Partial confounding was used in the design of the final experiment since only four treatment combinations could be run in one day and day to day variation was expected.

Consulting in the Physical Sciences

Much of the consulting in the physical sciences is done by Dr. H. T. David, who holds a joint appointment in engineering, and his associates.

Dr. David consulted with an agricultural engineering student on setting up an experiment to test the effect of certain factors on spray droplet size distribution. These factors are grouped into basic physical factors such as viscosity, and other factors such as stream velocity, all being conveniently summarized by two dimensionless quantities. The adequacy of this summarization was tested by a preliminary experiment which achieved various levels of these two quantities by first varying exclusively the basic physical factors, and then exclusively the other factors.

In civil engineering, Dr. David consulted with a staff member on the setting up of rules for discarding extreme observations, both in small and in extensive experimental series. He consulted with one civil engineering graduate student on the fitting of traffic counts to certain road characteristics by multiple regression, and with another on predicting material void-ratios by statistical packed-sphere models.

One civil engineering graduate student consulted Dr. David on setting up an experiment to determine how the formation of certain chemical by-products of cement curing vary with curing temperature and time. In the same area, Professor C. Philip Cox and Pat Conn were consulted on applications of probit analysis to experiments on the stress characteristics and fatigue life of strand used in reinforced concrete with particular attention toward the determination of the fifty percent and ninety percent endurance limits.

With an industrial engineering graduate student, Dr. David consulted on the setting up of a model for a milk processing plant designed to optimize factors such as the number of loading docks and the allocation of routes to tank trucks.

He consulted with a chemical engineering graduate student on the setting up of a fractional factorial experiment designed to detect the effect of time, as well as the effect of the factors. With a chemistry graduate student he discussed setting up confidence bands for functions describing one reaction when the parameters of such a function are estimated in connection with another.

A traffic engineer requested help from Dr. David on the establishment of tolerance intervals for traffic counts and the estimation of quantiles of such counts, and on the correlation between actual local traffic counts and average mileage figures.

Also in the physical sciences, Dick Johnson consulted with a staff member in agricultural engineering on the multiple regression of corn drying rate on temperature, wet-bulb depression, saturation deficit and relative humidity. The project also included an inverse confidence interval estimate on days required from silking for corn moisture to reach thirty percent.

Dr. Joseph Sedransk was asked for assistance by a student in architecture. The problem involved parking facilities available for cultural events at Iowa State and Dr. Sedransk was consulted on the planning of such a study.

Consulting in the Animal Sciences

Under Agricultural Experiment Station Project 101, Dr. Donald Hotchkiss has consulted with numerous staff members and students from the beef, dairy, swine and poultry departments.

One of the most interesting projects was a cooperative effort with Dr. Virgil Hays, swine nutritionist. A series of three standardization trials were run with pigs to strengthen the argument for using variation among pens of pigs, rather than among pigs within a pen, as the estimate of experimental error. This study confirmed the existence of pen to pen variation as well as even larger litter to litter differences.

A review of actual experiments did not always confirm a positive among pen variance component. Therefore, it was proposed that a negative correlation of animal to animal response within a pen caused by intrapen competition could easily result in a larger within pen mean square than among pen mean square. Nevertheless, the among pen mean square remains as the valid error for testing treatment effects, as is shown below.

Source	Expected Mean Square
Treatment	$\sigma^2 + (n-1)\rho\,\sigma^2 + n\sigma^2_P + np\sigma^2_T$
Pens w/Treatment	$\sigma^2 + (n-1)\rho\,\sigma^2 + n\sigma^2_P$
Pigs w/Pen w/Trt	$\sigma^2 - \rho\sigma^2$

On another experiment on which Dr. Hotchkiss was consulted, a balanced incomplete block design incorporating a non-parametric testing procedure, as outlined by Durbin, was used to evaluate the palatability (acceptability) of several forages using farm animals. This experiment has prompted the investigation of other non-parametric techniques for similar studies in which an inherent correlation exists between the actual consumption of two or more rations offered simultaneously.

Assistance in the design of experiments was requested from Dr. Hotchkiss when increased precision was needed. For example, the dairy department used a crossover study where each cow was fed each ration over several periods in a digestion trial. Another experiment compared different levels of ration "Concentration" which was fed to dairy cows over successive periods during which milk production responses were observed. The number of samples to run for artificial rumen work and bacteriology studies were determined from results of previous studies.

Dr. Hotchkiss participated in another project where he proposed proper sampling techniques for estimation of the effects of stage of growth and other environmental factors on the bloat potential of legume forages. After adjustment for these factors, correlation of an estimated bloat potential with the observed field bloat in cattle will be made.

In yet another project, Dr. Hotchkiss was asked to propose a design in which the researcher will use correlation and regression techniques. The research is designed to choose the optimum procedure for evaluating milk quality when choosing from among several types of bacterial counting techniques. The counting techniques which correlate highest with quality farm milk production conditions will be further examined to check the reliability of the test for milk stored under varying conditions of temperature and time.

Variance components were estimated by Dr. Hotchkiss in two separate studies. From one, a repeatability of litter size and weight characteristic from the first farrowing to subsequent farrowings were estimated.

In a second study, the magnitude of the variance components was used to determine the optimum allocation of resources in studies using dogs subjected to kidney operations.

Professor C. Philip Cox and Herman Wiedenhofer, D.V.M., have consulted with a graduate student in animal science on the planning and analysis of investigations on the changes in concentration of FSH and LH pituitary secretions in the pig during gestation and post-farrowing. This collaboration has led to statistical research on the appropriate bioassay techniques.

Professor Cox also consulted with Dr. Lloyd Anderson in the Department of Animal Science. The project involved analysis of experiments on the progesterone concentrations in pig ovaries with particular reference to compensation effects in the uterine horns.

Consulting in the Plant Sciences

Dr. Foster Cady, under Agricultural Experiment Station Project 101, continued his consulting activities in the plant sciences. He was assisted on some of the projects by graduate students Chang-Sheng Shih and Paul Johnson.

Of particular interest during the past year have been several problems involving models with non-linear parameters. In problems where biological theory indicates that a non-linear model with an additive error should be used, the experimenter was encouraged to fit the non-linear model. Transforming a non-linear model so that the parameters of the transformed model may be estimated easily involves consideration of the random error component.

For example, a plant physiologist wanted to test that the relationship between radiant energy interception (R) by maize and leaf area (L) is of the form $R = \frac{KL}{1+KL}$ where K is an unknown parameter. Many experimenters in the past have merely made a transformation, e.g., in this example, the reciprocal, to obtain the linear model $Y=BX$ where $Y = \frac{1}{R} - 1$, $B = \frac{1}{K}$ and $X = \frac{1}{L}$.

In making a transformation to obtain a linear model, experimenters often overlook the placement of the epsilon term in the original model and make the error additive in the transformed model. In the above case, the equivalent original model would be $R = \frac{KL}{1+KL+KL\,\epsilon}$, which would not be considered a realistic model by the experimenter.

An agronomist desired to compare, for the relationship between yield and a given nutrient, a quadratic polynomial model with an inverse polynomial model which permits asymmetric response about a maximum yield. A simple procedure of fitting an inverse polynomial model as proposed by Nelder is based on the assumption of an error variance proportioned to the square of the expected response. If this assumption is valid, the method of weighted regression should be used to fit the quadratic polynomial. If a common variance is suggested by the data, however, the method of successive approximation should be used to fit the inverse polynomial model.

Model construction was the primary problem in an experiment on which Dr. Cady and Shih consulted, studying the distance and direction effects of 2,4-D on the growth of grapes.

The contaminating source was placed in the center of a circular experiment. It was hypothesized that the rows near the center would be heavily damaged and that the damage would decrease with distance until a stimulating effect would be noticed due to the hormone effect of 2,4-D at low concentration. The effects of 2,4-D were also hypothesized to be affected by the direction of the air movement; therefore, some sectors of the experiment would be damaged more than others due to the prevailing wind.

A model was constructed using polynomial terms to approximate the distance effect and trigonometric terms to represent the sector effect.

The response surface designs by Box and co-workers represent a situation where designs have been derived specifically for application in the physical sciences. Experimenters in the biological sciences have interest in estimating a response surface with a minimum number of treatment combinations and have used the Box designs. Dr. Cady has given assistance on several projects to modify these designs to be more appropriate for field experimentation in the plant sciences.

In a forest fertility study with nitrogen, phosphorus and potassium as the interested variables, suggestions were made for replication instead of repeating the center point and the use of $\pm$ 2 units for the star points.

An agronomist has been concerned with the comparisons of complete factorials and abbreviated factorials with the Box designs noting in particular the precision of the interaction effects. Also of major concern has been the inclusion of a check plot in the Box designs.

In two other experiments, one involving brown stem rot syndrome development in soybeans and the other studying the effect of light intensity on pine photosynthesis, interest has existed in the comparison of deviations from regression with experimental error. It does not seem to be clear to all users of a computer regression program that the deviations from regression mean square cannot routinely be equated with the experimental error.

The problem of whether measurements made over time, e.g., cuttings of turf grass, and the interaction of time with the basic treatments should have a separate error is periodically encountered. The major premise used in these discussions is that the time measurements are repeated measurements from the same experimental unit; consequently, one would hypothesize that the error involving the time measurements should not include plot error. Other examples include water movement in columns with different radiation levels and nematode measurements in field plots.

Wrinkles in regression analysis constantly arise. When orthogonal polynomials cannot be used and the actual levels of the independent variable (X) are used, high correlations exist among the powers of X, presenting problems in a regression computer program. A procedure developed by Dr. Wayne Fuller has been used for eliminating these high correlations.

The desirability of a covariance adjustment for moisture in a moisture by maturity factorial experiment in agricultural engineering, when the data had to be pooled over maturities for the covariance adjustment, was evaluated. A computer program written by Howard Jespersen for plotting yield isoquants in two dimensions has been explored and used. Weighted regression was advised in one situation where the weights were the number of observations for each combination of variables.

The interpretation of a questionable correlation coefficient in a sorghum breeding experiment where the data had been pooled over two years was given. Interpretation was also a major problem in a study investigating the quantitative relationship of factors affecting water yield from small watersheds.

The design of a new rotation experiment was developed for a corn-corn-corn-soybean rotation where there was major interest in the contribution of the soybean crop to the nitrogen requirement of the corn and the comparison with applied nitrogen rates.

The analysis of rotation experiments has been of major importance and has been set up as a special Agricultural Experiment Station project, number 1578 under Dr. Cady and Dr. Fuller.

Graduate student Dick Johnson also has been involved in consulting activities in the plant sciences. Most of his work has been with graduate students in agronomy. The projects on which he's been consulted have included the effect of time of occurrence of moisture stress on yield and the yield components of soybeans; estimation of genotypic correlations among eight characters in maize; design of an experiment to compare yield reduction from inbreeding in two alfalfa populations.

Dr. Oscar Kempthorne consulted with staff and students in agronomy on the analysis of plant breeding experiments. He assisted with the interpretation of data on the accumulation of dry matter and the moisture content of corn, in association with a staff member in the Department of Agricultural Engineering.

Consulting in the Biological Sciences

In the biological sciences, Dr. T. A. Bancroft consulted with and advised Dr. Richard P. Oates, a National Institutes of Health fellow who was the first postdoctoral student at Iowa State to combine study in statistics and bacteriology.

Dr. Bancroft and Dr. Oates worked with Dr. Loyd Quinn, Department of Bacteriology, on an NIH grant in bacteriology. The research project involved development of an optimal growth medium containing 80 ingredients for rumen protozoans. By using split plot designs an attempt was made to distinguish the nutritional requirements of the protozoans, and learn which of the 80 ingredients under consideration were necessary for their survival.

Dr. Om P. Aggarwal and Dr. Wayne Fuller consulted with Dr. G. S. Firkins of the veterinary diagnostic laboratory on the development of sampling procedures for a study in beef animals.

Dr. Donald Hotchkiss consulted with staff members from the veterinary school on the handling of data complicated by disproportionate assignment of the animals to treatment groups. A recent study concerning the effect of iron and endotoxin injections on blood of small pigs was done by varying pigs in each group. Death losses further destroyed the balance of the study over time, necessitating repeated evaluation of the data using the regression program for the computer.

Dr. Hotchkiss consulted with staff members in zoology and entomology on setting up multiple comparisons for evaluating the effects of numerous chemicals on the control of corn root worm. In a study of fish growth, a comparison was made of the length, weight relationship of fish from differing locations in the river at various times of the year to see if a differential growth takes place.

Dr. Joseph Sedransk worked with a graduate student on a fisheries biology problem. He assisted with the analysis of data in a study to determine the effect of exercise on the pH of fish. He consulted with another student on a project involving the estimation of fish populations.

Professor C. Philip Cox and Donna Ruhl consulted with a graduate student in veterinary physiology on the planning and analysis of a $3 \times 2 \times 2$ factorial experiment for investigating the effects of exposure to dust on the elasticity of guinea pig lung tissue. A highly significant ($P < 0.001$) linear regression indicated a decline of lung elasticity with increased exposure, a finding consistent with the results of histological examinations by the research worker.

Professor Cox also consulted with Dr. J. R. Andersen, Department of Veterinary Hygiene, on the determination of the LD 50 of E. coli endotoxin. And he consulted with a graduate student in entomology on results of dietary treatments on pupal weight, mortality and larval pupation rate of the European corn borer.

Working under the support of Agricultural Experiment Station Project 1448, Dr. Ed Pollak provided assistance to personnel in the genetics department doing research on the effects of radiation on small grains and Drosophila.

Dr. Oscar Kempthorne consulted with staff members in poultry breeding on the design of a mating scheme in connection with the assessment of effects of blood group factors on economic attributes.

He consulted with staff and students in animal breeding on interpretation of data from experiments on learning in swine, and with staff and students in animal breeding and dairy husbandry on problems of analysis and interpretation of production records.

Off Campus Consulting and Advisory Assignments

In addition to their regular consulting duties for campus departments and individuals, staff members frequently are called upon to serve in an advisory capacity to professional groups elsewhere. This may involve travel on the part of the consultant, the group seeking advice may visit the campus or the consulting may be done by mail. These examples illustrate this type of consulting activity.

Dr. Om P. Aggarwal is consulting by mail with Dr. P. V. Sukhatme, Director of the Statistics Division of the Food and Agriculture Organization of the United Nations. Dr. Sukhatme is completing the second edition revision of his book, *Sampling Theory of Surveys with Applications*, published by the Iowa State University Press.

Dr. Aggarwal is also consulting by mail with F. Rahim Momard, Director General of the Economics Department, Ministry of Agriculture in Kabul, Afghanistan. The project involves data processing and analysis of a pilot census in Afghanistan.

Professor C. Phillip Cox consulted with Dr. D. B. Stone and his colleagues at the University of Iowa College of Medicine on the design and analysis of experiments on the effect of sulfonylurea drugs *in vivo*.

Dr. T. A. Bancroft continued consulting work with Dr. T. A. Brindley and staff of the European Corn Borer Laboratory. A report of previous work has been published and appears in the publications section of this annual report.

Dr. Bancroft, Professor Cox and Dr. Akio Kudô consulted with R. D. Jackson, United States Department of Agriculture collaborator, Department of Zoology and Entomology, on the analysis of results investigating the effects of a sterility-inducing chemical on the European corn borer.

Dr. Kudô consulted with members of the corn borer laboratory in Ankeny on the problem of optimum timing for spraying insecticide against the insect. He proposed a mathematical formula to discover the optimum time for spraying for the experiment.

Dr. James Prescott consulted with Mr. Vermeer of the United States Department of Agriculture on linear discriminant functions. A set of routines was developed to estimate the coefficients of a linear discriminant function. These routines were applied to two samples of participants and non-participants in the USDA feed-grain program from West Texas and other Corn Belt states.

Donald Soults did consulting work for IBM in White Plains, New York, in the area of mathematical programming. IBM sent a programmer to Ames from London, England, for three months in the fall of 1964. During that time a relatively sophisticated linear programming system for the 1400-1311 family of computers was designed and programmed. The programming system has now been released by IBM and is being widely used in this country and in England.

Numerical Analysis-Programming Group

The Numerical Analysis-Programming Group provides consulting services in numerical analysis and computer programming of statistical problems, consultation in statistically-oriented computer techniques, computer programming, and processing of data requiring the services of an analyst-programmer.

Group members function in a liaison capacity between the research and the computer, and they have

developed a number of general purpose programs for the IBM 7074-1401 which are used in various consulting problems.

Dr. William Hemmerle, who was in charge of the Numerical Analysis-Programming Group, spent much of his time this year on an NSF-sponsored research project to develop and implement a statistical computing system which is practical, reasonably machine independent and which accepts an algebraic description of the problem to be solved. His work, and that of graduate students James Blinn and John Schlater who assisted him, is reported in the research section of this annual report.

Dr. James Prescott, who holds a joint appointment with the Department of Economics and Sociology, consulted on and ran a linear programming model for scheduling faculty activities in that department. The project resulted in a paper given at the Midwest Economic Association meetings by Dr. D. L. Winkelmann.

With Dr. James Strain, Department of Economics, Dr. Prescott consulted on the linear programming model for an Iowa milk shed. The model chooses optimal milk delivery routes assuming surplus milk routing to six alternative cheese plant locations.

He consulted with a graduate student on population projections. This routine projects population by sex and age class, assuming constant fertility and death rates, for 1970 and 1980. Projections were made for a southern Iowa county for use in planning optimal school district size and education needs in the years of projection.

With another graduate student, Dr. Prescott worked on a retailing-wholesaling simulation. This resulted in programming a 52-week simulation study of retailing-wholesaling demands for meat products.

Dr. Prescott and Professor Norman Strand are co-leaders of a tax survey in Iowa being directed by Dr. Arnold Paulsen, Department of Economics and Sociology. The sample for this study was drawn in January and includes owners of real and personal property in Iowa.

Twenty-three counties were selected as first stage units. A subsample of holdings of real and personal property (agricultural, mercantile and residential) was drawn from these 23 counties. The sample will be used to make estimates of taxes paid by various income and occupational groups.

Donald Soults has consulted with graduate students in economics on mathematical programming problems. These projects have included linear programming, convex programming, transportation models and recursive linear programming to be used in research directed by Dr. Earl Heady.

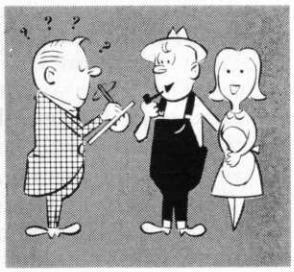
Soults also has done some additional work in convex programming. Using a computer program based on the Hartley-Hocking algorithm "Convex Programming by Tangential Approximation," it has been possible to optimize non-linear econometric models. One model reflcts production, transportation and consumption activities in which both prices and activity levels are variables. Work is progressing toward the solution of even larger, more sophisticated models.

James Olin is devising a suitable programme for Monte Carlo evaluation on the IBM 7074 for joint research being conducted by Professor C. Philip Cox, Dr. T. R. Roseberry and Olin.

In Dr. Roseberry's Ph.D. thesis, written under Professor Cox, techniques are described whereby concomitant information can be incorporated into Wald-type SPRT. Two procedures are given which enable a decision between two hypotheses to be reached at an earlier stage than if the concomitant information is ignored.

In the first of these the computations are relatively simple and give good results for moderate sample sizes although the method is strictly valid for large samples only. The second procedure does not involve asymptoticity assumptions but the appropriate calculations are involved and although no extensive evaluation of the test has been made, initial results are promising. Olin, with Cox and Roseberry collaborating, is considering the construction of special tables to facilitate practical applications of the test.

Survey Group



The Survey Group of the Statistical Laboratory provides direct operational services to the rest of the campus on all aspects of sampling, surveys and census-type studies. Consulting services are combined with operational work through the financing of the Statistical Laboratory, the Statistics Department, the Iowa Agricultural and Home Economics Experiment Station and the Sciences and Humanities Research Institute.

The Survey Group participated in a number of studies during the year which were administered jointly by the Statistical Laboratory and some other university, institute, state or federal agency, such as the Center for Agricultural and Economic Development, United States Department of Agriculture, Bureau of the Census, Iowa Conservation Commission and the Ohio Division of Wildlife.

Professor Norman Strand and Dr. Wayne Fuller are co-leaders of Agriculture Experiment Station Project 113, "Statistical Services for Sampling Investigations." Under this project, many departments on campus request consultations on the design and analysis of various studies. In some projects samples were drawn and field collection of data were performed under the direction of the project personnel.

Coding of a farm buildings study was completed during the year and much of the analysis has been completed. The study was designed to make a physical inventory of farm buildings, their current and past use, and the extent of new building construction and remodeling. It was also planned to investigate

the many factors affecting the use of present farm buildings and the construction of new ones. Some of the data were used in the doctoral thesis of John T. Scott, Jr., in economics.

During the summer of 1964, field work was completed on a study of occupational changes directed by Dr. Jon Doerflinger and Dr. Ward Bauder, Department of Economics and Sociology. Mrs. Marjorie Mason, Thomas C. Jetton and Mrs. Hazel Cook supervised the field work assisted by sociology graduate students. Coding on this survey has been completed. Consultation on sampling and field work procedures was provided by Professor Strand and Harold Baker.

Two telephone surveys were done in cooperation with the Department of Technical Journalism. Bulletins on corn dryers and lawn care were sent to two samples of people. On the corn dryer study, one group received the bulletin on request while the other group received it in a blanket mailing to farmers known to have corn acreage. On the lawn care study, one group received the bulletins at no cost; the other people were asked if they would pay for the materials.

Individuals were then telephoned to determine their interest in the bulletins and to measure the relative interest of the two groups. William Berkland received his M.S. thesis, "The Influence of Effort in Acquiring a Publication on Its Readership and Acceptance," on the corn dryer study. Data collected in the lawn care study, which has not been completed, also will be used for an M.S. thesis. When both studies are completed, the final analysis will be presented.

In home economics, consulting services and assistance were given for a Monroe County nutrition study for the Department of Food and Nutrition, a credit study on young married people for the Department of Home Management, a household appliances and equipment study of homemakers 65 years of age and older with the Department of Household Equipment and a used clothing study for the Department of Textiles and Clothing.

A child care study was conducted in Webster City in cooperation with the Child Development Department to find out what arrangements were made for children when working mothers were away from home during the day. Mothers with children under 13 years of age were included in the sample, which was drawn by the Survey Group. The Survey Group also supervised the interviewing and collection of data.

Preliminary work has been done on a survey of factors relating to the diets of preschool children, with field work scheduled for fall 1965. The study is planned to obtain a picture of the dietary intakes and eating habits of preschool children living in the 12 north central states, in order to determine the type of nutrition education needed by those in charge of their feeding.

The second year of a five-year study of nutritional characteristics of Iowa high school students was completed under the direction of Professor Strand, with Thomas C. Jetton assisting. This work is being done in cooperation with the staff of the Department of Internal Medicine, University of Iowa. Coding, punching and tabulation of the data from the initial year was completed and preliminary findings will be published in 1965.

The same University of Iowa staff members are participating in a study of the proneness to coronary attack among apparently healthy persons employed in Iowa businesses and industry. The field work is nearing completion and the Survey Group will do the coding, punching and tabulation. Consulting concerning the statistical and sampling aspects of this project has been done by Professor Strand and Jetton.

The data collected from a food consumption study in Webster County has been coded and the calculations on the consumer preference section of the study have been completed. Qualitative data was quantified using a scaling technique to show the consumers' attitudes and values at the time of purchase and at the time of consumption of meats.

The Survey Group, with Professor Strand as project director, is conducting a field study of the completeness and accuracy of congenital malformation reporting on certificates of live birth in Iowa during 1963. The study is jointly sponsored by the Epidemiology Branch, Division of Dental Health, and the Division of Vital Statistics, National Center for Health Statistics.

The purpose of the Iowa study is to compare congenital anomalies which were diagnosed and recorded in the hospital records of children born in Iowa in 1963 with congenital anomalies reported on birth certificates of the same children. Iowa was selected because cleft lips, cleft palates and other malformations have been reported with a relatively high frequency.

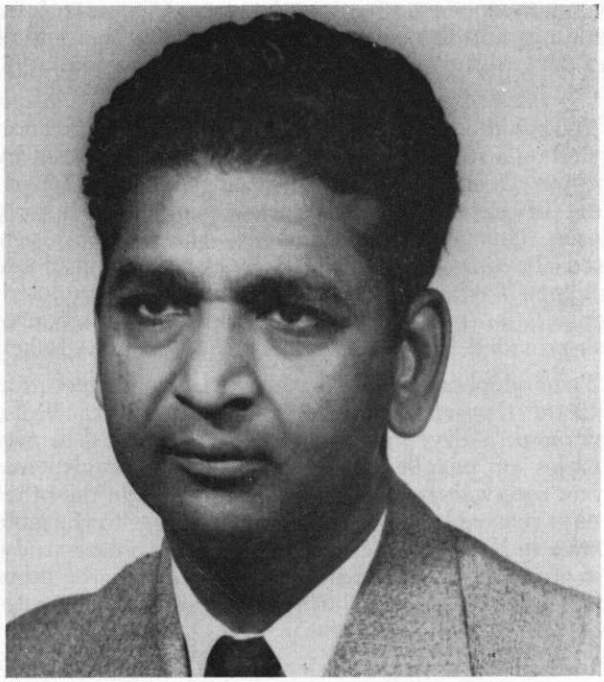
The Epidemiology Branch views the study in Iowa as a means of learning more about the true incidence of malformations and of identifying significant characteristics of hospitals which would aid in developing criteria for the selection of a sample of hospitals for an expanded study representative of the entire National Cleft Lip and Palate Intelligence Service. The Division of Vital Statistics is equally concerned with compiling data which might be applicable to improving vital statistics registration on a national basis.

The Survey Group has recruited and trained interviewers for the project and information is now being collected. It is expected that the study will be completed in 1966.

Dr. Om P. Aggarwal directed final reporting on the third farmer attitude survey done by the Division of Wildlife, Department of Natural Resources, Ohio. The description of the survey was written as Phrensi Svasti-Salee's M.S. thesis, which is abstracted in the publications section of this annual report. By conducting the farmer attitude survey, the Division of Wildlife was attempting to discover the ideas and opinions of the land-owning group, which controls 95 percent of Ohio's outdoor recreational opportunity.

The division will use the findings of the surveys to better plan future programs and policies which involve rural land, which it is hoped will aid in more efficient and better oriented programs to take fuller advantage of the natural resource potential.

In addition to designing the survey, the Survey Group edited, coded and tabulated the material.



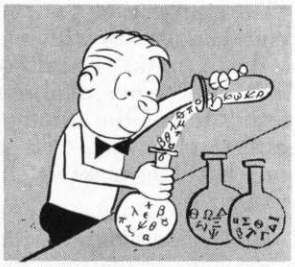
Om P. Aggarwal, associate professor, joined the staff of the Statistical Laboratory in September, 1963. He had previously been at Iowa State as a graduate assistant from 1949-51. He has B.A. and M.A. degrees in mathematics from Delhi University and received his Ph.D. in statistics from Stanford University in 1953.

Dr. Aggarwal has been on the faculty at the University of Washington and Purdue University and has served as a visiting professor at the University of Alberta, Canada; the University of Saskatchewan, Canada, and the University of San Marcos, Peru. Before joining the staff of the Statistical Laboratory he was a statistician with the United Nations Food and Agriculture Organization in Chile and Peru.

At Iowa State Dr. Aggarwal teaches Advanced Design of Surveys and Seminar on Design of Surveys. He is a member of the graduate faculty and supervises the research of graduate students, especially those in survey sampling.

Dr. Aggarwal holds membership in the American Statistical Association, Biometric Society (ENAR), Institute of Mathematical Statistics, Indian Society of Agricultural Statistics, Phi Kappa Phi, Pi Mu Epsilon and Sigma Xi.

Current Research



In the research program of the Statistical Laboratory, both the development and extension of basic theory and its application to new statistical methods and techniques are emphasized. The Laboratory cooperates with other research institutes and experiment stations on the campus to arrange programs of statistical research and obtain support through joint grants and projects. Many studies of a fundamental nature are supported by such grants and contracts with off-campus agencies. In most instances they provide for supervised graduate research on topics proposed by the staff. The Statistical Laboratory budget, however, supports only projects which are of specific interest to regular university research programs.

Research in General Methodology and Theory

Dr. Leroy Wolins' research interest continues in the area of methodological problems in psychological measurements. His most recent endeavor is to develop a procedure for estimating the proportion of variance of a measure attributable to each source when each measure has three sources of variance: method variance, trait variance and error.

The experimental design is such that each observational unit is measured under every combination of method and trait. The design used was a type of three-way factorial.

These variance components may be estimable with as few as three methods and three traits when it is tenable to assume method variance independent of trait variance and the intercorrelation between traits may be explained by one factor and the intercorrelations among methods may be explained by one factor.

Dr. Ed Pollak, working under the support of Agriculture Experiment Station Project 1448, did some mathematical research on the fate of newly introduced genes in subdivided populations. The subpopulations are not completely isolated and can be subject to differing intensities of selection.

Work is now being done on an attempt to calculate the probability that the line descended from a gene survives in a finite subdivided population of constant size. The general problem involves genic selection with different intensities in different partially isolated subpopulations.

Dr. Wayne Fuller and Dr. Joseph Sedransk have continued research on the design of surveys and analysis of data, under the support of Agricultural Experiment Station Project 1005.

Research on an application of sequential sampling to analytical surveys was conducted. A procedure for the case of unknown population variances was developed, and a numerical evaluation of some approximate methods was carried out.

Research was initiated on the planning of analytical surveys when a fixed factor linear model is considered to be appropriate.

Research on regression and unbiased regression estimation was continued and research was conducted on rotation sampling.

Prediction of Election Results

A follow-up study to a previously reported application of the "post stratification" technique to a statewide election prediction was carried out by the Statistical Laboratory in the 1964 general election under the direction of Dr. Joseph Sedransk and Dr. Robert Clyde, news manager of WOI.

Even though early returns in the 1964 Iowa general election foretold the heavy Democratic landslide in the state, the estimator used in this study accurately predicted, from a very small sample, the final vote percentages for a number of races. These predictions, based on election returns obtained after the closing of polls on November 3, 1964, were used as a part of the election night report of WOI-TV.

Count-by-county returns were transmitted to the Iowa State University Computation Center via a transceiver transmission system which permitted automated punching of data cards for immediate computer analysis. James Blinn, C. C. Mosier and David R. Paul assisted with this analysis.

Each Iowa county was assigned to a stratum representing a cross-classification of voting history and current population; these two variables were assumed to be pertinent for the estimation of final vote percentages. Previous experience had suggested that counties within a stratum would hold to similar voting patterns. By assigning weights to the strata and combining the estimates from all strata, it was possible to obtain an overall estimate superior to the traditional periodic reporting of "uncorrected" vote percentages.

A stratified ratio estimator was developed as the ratio of two estimates: estimated Democratic vote/estimated total vote. Average votes per precinct in each stratum were used to obtain these figures. To measure the effectiveness of the stratified ratio estimator, an estimate of its variance was computed by partitioning the available vote data into nine non-overlapping time periods.

Since this procedure performed within the limits of acceptable accuracy in two successive Iowa gubernatorial elections, it was of interest to explore the possibility of generalizing to other statewide election contests. Specifically, the stratified ratio estimator was used to "predict" the outcome of the 1964 presidential election in Iowa and the 1962 Iowa senatorial contest. The estimator performed consistently in projecting, from partial vote returns, percentages very near those of the final results.

NIH Research

Nine graduate students have benefitted from the National Institutes of Health training grant program during 1964-65.

Fred Ramsey, who investigated a particular type of non-stationarity in stochastic processes, received his Ph.D. degree under Dr. K. C. Chanda in August.

Thomas D. Roseberry received his Ph.D. degree in February under Professor C. Philip Cox. His thesis gives two procedures for incorporating concomitant information into Wald-type SPRT, which enable a decision between two hypotheses to be reached at an earlier stage than if the concomitant information is ignored.

James R. Veale completed his research in the area of statistical tests for outliers and the estimation of parameters of interest after making the test. He received an M.S. degree in May, under Dr. D. V. Huntsberger. Abstracts of all of these theses appear in the publications section of this annual report.

Steven Selvin, a premasters student, and James Gebert, a predoctoral, joined the program March 1. Other predoctoral students continuing their studies and research under NIH support are Patricia Conn, John Peter Johnson, Charles Sampson and Donna Jean Ruhl.

The doctoral thesis research by Mrs. Ruhl, working under Professor Cox, is concerned with the utilization of sequential experimental techniques in bioassays with continuously distributed responses. As one preliminary result the usual Wald sequential probability ratio test (SPRT) has been extended to the case of asymmetric alternative hypotheses with unequal probabilities of Type II error.

Professor Cox and Mrs. Ruhl also have been conducting research on the simplified computation of confidence intervals for relative potency estimates. The Fieller's theorem calculations for confidence interval estimates of relative potency are notoriously cumbersome. Equivalent alternative formulations have been developed which considerably simplify the procedure both for parallel line and slope-ratio assays.

The advantages are obtained by incorporating into the computations for the interval estimate quantities which are necessarily computed for the appropriate analyses of variance. A description of the procedures, with examples, has been prepared for publication.

Patricia Conn has been doing her doctoral research under Dr. H. T. David. It concerns the asymptotic behavior of unabsorbed paths of the random walks between two absorbing barriers that arise in sequential analysis. Her work is reviewed in the report on Dr. David's NSF research project, "Problems in Random Walk and Statistical Applications."

John Johnson's doctoral research under Dr. T. A. Bancroft has been on the power of test procedures for certain incompletely specified fixed models, as reported under Dr. Bancroft's NSF research project, "Incompletely Specified Models Useful in Life Testing."

NSF Grant for Remodeling

The special project to remodel and renovate the third floor of the Service Building was completed in June. The project was undertaken to provide more adequate physical housing for research and research-related activities and thus to strengthen the research potential of the university. The NSF grant was matched by equal funds from the State of Iowa.

The NIH Group, Industrial Statistics Group and the staff in general statistical theory have moved into the new quarters, which also includes two seminar rooms, a conference room and a machine laboratory for graduate students.

The Statistical Laboratory and the Computation Center now occupy the entire first and third floors of the Service Building, and the second floor in the new wing, with the Numerical Analysis-Programming Group and some graduate students still housed in temporary buildings.

Multivariate Analysis and Multiple Inverse Sampling

Dr. Akio Kudô is principal investigator of National Science Foundation Project GP-3918 for research on Problems in Theoretical Statistics. The grant went into effect January 1 and the study will include two major areas:

(1) Test with Restricted Alternative Hypothesis in Multivariate Analysis.

Dr. Kudô already has written a paper, "Multivariate Analogue of the One-Sided Test," considering what test is appropriate to determine whether the means are slipped to the right, given a multivariate normal population with known variance matrix. Work in this area was motivated by the recognition of the importance of restriction on the parameter space. The research proposal is based on the same motivation.

These problems also have practical importance. For instance, genetic as well as circumstantial influences on some of the anthropometric measurements of man, such as height, weight, etc., are believed to be of this type, and the ordinary methods of testing the significance are lacking in view of this belief.

(2) Multiple Inverse Sampling.

Dr. Kudô also is co-author of a paper on "Some Considerations of the Multiple Inverse Sampling Methods." This is a special type of sequential multinomial sampling. Dr. Kudô hopes to investigate the problems in this area under full generality.

Statistically Oriented Computer Languages

Dr. William Hemmerle directed research project GP-3239, supported by the National Science Foundation, to develop and implement a statistical computing system which is practical, reasonably machine independent and which accepts an algebraic description of the problem to be solved. He was assisted by graduate students James Blinn and John Schlater.

The Numerical Analysis-Programming Group of the Statistical Laboratory previously had developed an analysis of variance compiler-monitor type system called AARDVARK, which permits an algebraic specification of the statistical model for all balanced complete structures.

Under this new research grant, work was begun to extend the present AARDVARK language to include hypothesis specification, tests of significance, regression models, models for incomplete structures such as Latin Squares and Lattices, models for the general non-orthogonal case with fixed effects including interaction terms, models with multiple covariates, as well as factor analytic models.

This extended system has been called AARDVARK II, and research to date can be separated into two categories:

a. The development of algorithms for computation and input/output that base their operation on certain arguments: parameters, lists, arrays, etc.

b. The development of a statistically oriented language amenable to translation into the arguments required by the algorithms and the construction of a scan routine to accomplish this translation by scanning the problem statements of the language.

With AARDVARK there are certain alphabetic restrictions imposed in writing the algebraic model, and external pooling specifications must be given in some cases to obtain appropriate sums of squares. The new algorithm developed for AARDVARK II removes all these restrictions and at the same time is more economical with respect to computer time. The new algorithm also has the capability to compute residuals, or estimates, for any term in the model, which was not previously possible. An external pooling function has been retained for the sake of generality. An interesting feature of the new algorithm is that an analysis without pooling specifications is merely a special case of the general case including pooling specifications. This implies of course that pooled residuals are obtainable.

In the area of analysis of covariance, AARDVARK II has essentially full capability for the balanced-complete case. To round out the processing of problems associated with balanced complete structures, a subroutine to compute variance components and F values for tests of significance was incorporated into AARDVARK II.

Work is now proceeding to incorporate non-orthogonal analyses of variance into the regression framework by automatically manufacturing the restrictions, and indicator variables based on these restrictions, required to produce a system of equations of full rank. The mathematics of this has been established and the computing procedures outlined but not detailed. Their implementation will provide for analysis of covariance in the non-orthogonal case and missing value computations as well as analysis of variance.

An initial input phase is planned for AARDVARK II to handle such things as data sorts, pooling of cross-product matrices in regression, transformations, and to provide for an analysis on means.

A substantial amount of symbol manipulation is necessary in translating problem statements into algorithm arguments, which creates problems with respect to machine independence. Specifications have been written for the scan routine which will process problem statement cards. A syntax of the problem statements has been prepared detailing the way in which each of the statements may be written by the user.

Attention was given to methods for handling problems associated with balanced-incomplete structures. However to date no satisfactory algorithm has been developed to handle this entire class of problems in a general manner.

Consideration was also given to incorporation of capabilities for principal component analysis and factor analysis into AARDVARK II and the language syntax reflects this consideration. Algorithms have

previously been prepared by the Numerical Analysis-Programming Group that may be incorporated into the system compatable with algebraic specification by problem statement.

Problems in Statistical Inference

Dr. T. A. Bancroft continued as principal investigator for this National Science Foundation Grant GP-274 for research in theoretical statistics.

A Ph.D. thesis by Florence Tetreault, "A Statistical Outlier Methodology for Observed Points and Lines," was partially supported by this grant. An abstract of this thesis appears in the publications section of this annual report. Dr. B. K. Kale is attempting to initiate an extension of this work on outlier methodology.

A second Ph.D. thesis, by Ahmed Hassan El Mawaziny under the supervision of Dr. Robert Buehler, was also partially supported by this grant and is abstracted in the publications section. This study presents some theoretical results which can be applied to the problem of confidence limits for the reliability of series systems of k dissimilar components having exponential failure laws, and resulted in a paper at the Chicago statistical meetings.

A paper by Dr. Bancroft, "Analysis and Inference for Incompletely Specified Models Involving the Use of Preliminary Test(s) of Significance," was published in Biometrics in September and is abstracted in the publications section of this annual report.

S. R. Srivastava came to Iowa State in June to conduct research under this NSF grant. He was interested in developing an extension for test and estimation of the fixed model or linear hypothesis case to the situation involving two doubtful errors. A second problem undertaken involved estimation of a correlation coefficient given a known estimate of the population correlation and a doubtful estimate of this same parameter. It is expected that this research will be submitted for publication.

Incompletely Specified Models Useful in Life Testing

Work has now been completed on this National Science Foundation Grant GP-1855, with Dr. T. A. Bancroft as principal investigator.

Research conducted by Dr. Bancroft and Dr. Dale Richards of Brigham Young University, who completed his doctoral thesis under this grant at Iowa State, resulted in two invited papers at the Amherst meetings in August. One of these papers has been submitted for publication and the other is being prepared for submission.

A second Ph.D. thesis has been partially supported by this grant. Florence Tetreault received her degree in May and an abstract appears in the publications section of this annual report. Dr. Tetreault and Dr. Bancroft are preparing a paper based on this doctoral thesis on outlier theory and methodology for possible publication.

Research has been initiated and partially completed by Dr. Bancroft and graduate student John Johnson to extend the paper of Helen Bozivich, T. A. Bancroft and H. O. Hartley ("Power of Analysis of Variance Test Procedures for Incompletely Specified Models," 1956) to the fixed effects models and compare the inference properties with those of E. L. Lehmann's conditional procedures in multiple decision problems.

Problems in Random Walk and Statistical Applications

Research on National Science Foundation Project GP-1801, concerned with certain statistical aspects of random walk, has been completed under the direction of Dr. H. T. David, chief investigator.

One of the areas studied concerns the application of a planar reflection principle to random walk in the plane. An M.S. thesis by Richard Mensing, abstracted in the publications section of this annual report, deals with this subject. The thesis begins with a general formulation of the reflection principle which is then applied to computing the probability of absorption for certain types of discrete planar random walks and boundaries.

Research completed in the second area of multiple decision sequential procedures is reported in the doctoral thesis written by W. D. Lawing, Jr. This also is abstracted in the publications section of this annual report. The thesis explores the extent to which terminal likelihood ratios can be made to yield OC functions of sequential procedures other than Wald's SPRT when the unknown parameter indexes a distribution of Koopman-Pitman exponential type.

Exact OC bounds, analogous to Wald's OC bounds for the binomial SPRT, are computed at all p for a three-decision extension of Wald's binomial SPRT and on an infinite grid of p-values for a certain symmetric "wedge" procedure. Symmetric wedges also are used in constructing two-decision and k-decision procedures concerning the drift parameter of a Wiener process, for which exact OC functions are computed on infinite grids analogous to that arising in the binomial case.

Further work involves a sequential three-decision procedure concerning the drift parameter vector (μ_1, μ_2) of a two-dimensional Wiener process. The continuation region for this procedure, analogous to the band of the usual normal SPRT, is a cylinder with equilateral triangle base; its OC function is computed exactly on three lines in (μ_1, μ_2)-space, thus providing absorption probabilities for the absorption of the two-dimensional Brownian motion process at an equilateral triangle boundary.

A characterization of the usual normal SPRT also is given, as that member of a class of k-decision "wedge" procedures possessing a certain asymptotic optimum property.

The doctoral research of Patricia S. Conn, an outgrowth of the M.S. thesis of R. M. Mengido (1963), covers the third area of research under this NSF project. This concerns the asymptotic behavior of unabsorbed paths of the random walks between two absorbing barriers that arise in sequential analysis. Let E_n be the event *no absorption (decision) up to stage n.* The asymptotic (with n) conditional (given E_n) distribution D of sample path location at stage n can be used in the comparison of untruncated and truncated

plans. This is because D appears both in the asymptotic conditional (given E_n) probability of eventual "acceptance" under the untruncated plan and in the conditional probability of "acceptance" at stage n in accordance with a truncation scheme. The distribution D has been studied in the following three special cases: the binomial SPRT with $ln(p_1/p_0)/ln(q_0/q_1)$ rational, the SPRT for a normal mean with σ known, and the SPRT for the location parameter of a Laplace distribution with known scale parameter.

Monte Carlo Studies of Genetic Selection

The National Science Foundation (G-19218) and the Agricultural Experiment Station (Project 1508) jointly supported studies in genetic selection. However this work continued at a lower level this year, due to exhaustion of funds. Oscar Kempthorne continued as project director.

A. W. Qureshi completed his work on the action of truncation selection, with 40 segregating loci, and the results are being prepared for publication.

Some of the research of Charles Cress, working on a study of reciprocal recurrent selection and variations thereof, was supported by this project. An abstract of Cress' thesis appears in the publications section of this annual report.

The Role of Errors of Parameter Estimation in Index Selection

Oscar Kempthorne was chairman of this project jointly supported by the National Science Foundation (G-18093) and the Agricultural Experiment Station (Project 1505).

The terminal parts of Charles Cress' doctoral thesis research were supported by this project. A thesis abstract appears in the publications section of this report.

Some preliminary work on equilibrium under random mating with differential viabilities was done by Dr. Kempthorne, with a view to applying this to a study of Fisher's so-called fundamental theorem of natural selection.

Dr. Ed Pollak worked on two topics under this project. The first was the consequences of a system of selection in which there are two alleles, only a fraction of the population which is best in some sense is allowed to reproduce, and heterozygotes are superior in merit to both homozygotes. Equilibria were examined. In addition, it was shown that under some circumstances, selection could cause a decline in the overage merit of the population.

The second subject was the calculation of probabilities that a gene of say, type A, could survive, given that it originates in any of K ecological niches. It was assumed that in each generation some adults migrate from the niche in which they are born to some other niche in which they have all their offspring. These survival probabilities were calculated for both infinite populations and populations in which there are at all times N_i genes in niche i.

Analysis of Variance Procedures and Related Topics

Research done on the present and prior Aerospace Research Laboratories contracts, under the direction of Dr. Oscar Kempthorne and Dr. George Zyskind, has led to an increased understanding of the role of physical operations such as sampling and randomization in experimental design. The work has also led to certain mathematically general formulations.

Thus, rigorous definitions concerning the underlying nature of population and sample structures for a wide variety of cases have been given, and general unified results have been obtained for expected values of sample quadratic forms.

The studies done have explored at depth second moment conditions for a large class of arbitrarily complex situations. A bridge between these approaches and studies of arbitrarily high moments for relatively simple population structures, as initiated by Tukey and Hooke, was provided by Eugene Dayhoff in connection with research for his thesis. This came about through the firm development of generalized polykays applying to arbitrarily general balanced population structures, and through the demonstration of equivalence of generalized polykays of degree two and the cap sigma quantities used so extensively in the course of the development of the work at Iowa State.

Dayhoff has previously derived the variances and covariances of estimates of variance components as linear functions of generalized polykays of degree four. For more than two factors of classification the linear functions become lengthy and though the rules of their formation are straightforward, the implementation is a difficult and error prone process. Furthermore, for even moderate numbers of levels the evolution of the generalized symmetric means of degree four from the definitions is impractical because too many multiplications are required.

In the effort to make these computations economically feasible, the above two difficulties have been attacked by E. J. Carney. An algorithm has been developed, programmed and partly tested for the formulation of generalized polykays in terms of generalized symmetric means for arbitrary balanced complete structures. Algorithms for evaluation of the generalized symmetric means are complete and programmed with the exception of one needed subroutine which is being worked on currently.

An algorithm for the estimation of variance components for arbitrary balanced complete structures has been developed, and algorithms for formulation of the variances and covariances of the estimates in terms of the generalized polykays have been outlined and partly flow charted.

Dr. George Zyskind has also been giving serious preliminary attention to the incorporation of statements about the polykays into the general context of experimental structures.

After conducting an extensive literature review and performing power computations for the Fisher randomization, Wilcoxon, sign and F tests, exact analytical expressions for power have been developed by

Joseph Sedransk, assistant professor, came to the Statistical Laboratory in 1963.

Dr. Sedransk was graduated from the University of Pennsylvania in 1958 with a B.S. in economics and spent the summer of 1959 employed at the National Cancer Institute, Bethesda, Maryland.

He received his Ph.D. degree from Harvard University where he was a research assistant and teaching fellow in statistics. He also served as an instructor in psychology at Wellesley College.

During the past year Dr. Sedransk has taught Survey Design for Research Workers and Design of Surveys. He is an associate member of the graduate faculty.

In research, Dr. Sedransk has been concentrating on analytical studies with particular application to survey data. Papers on "Analytical Surveys with Cluster Sampling," "A Double Sampling Scheme for Analytical Surveys" and "An Application of Sequential Sampling to Analytical Surveys" will be published on his work.

While Dr. Wayne Fuller was on leave of absence during the year, Dr. Sedransk replaced him as researcher on the USDC, Bureau of the Census, research project.

He is a member of the Institute of Mathematical Statistics, the American Statistical Association and Beta Gamma Sigma.

T. E. Doerfler. A study has just been completed on the properties of these four tests for the paired experiment, or if one prefers, randomized blocks with two treatments. The study showed clearly the inferiority of the sign test of significance, the lack of knowledge of size under experimental randomization of the F test, and the lack of inferiority of the two other nonparametric tests to the F test even under normality.

Frank Martin has been engaged in a search for necessary and sufficient conditions under which the best linear unbiased estimator of a function $\lambda'\beta$ of parameters, estimable from two independent sources of information, is obtainable by simple weighting with respective variances. A general theorem on a necessary and sufficient condition has been derived. The particular ramification to the full rank case has been fully explored. Special interest is now being given to the combinability of intra and inter block information in the general class of incomplete block designs and in the class of factorial and quasifactorial designs.

Nearing completion now is a phase of the study on unbiased estimation of variance components and regression parameters as reported in Rodney Basson's doctoral thesis, abstracted in the publications section of this annual report.

Some research has been done to determine the placement of x-points which best determines the fitted functional relationship or some aspects of the relationship. If, for example, the true relationship is linear, and there is homogeneity of error over the possible range of x, it is best to place half of the observations at each end of the possible range. If one wishes to have maximum power with regard to a test of a quadratic effect, another placement is "optimal."

USDC, Bureau of the Census Research Project

Dr. Joseph Sedransk became the chief investigator on the USDC, Bureau of the Census, research project during Dr. Wayne Fuller's leave of absence as a postdoctoral fellow at Stanford University. This project is a continuing cooperative program of basic research in sampling, response errors and other fields of joint interest.

Dr. Sedransk worked on this study to provide some general principles to use in deciding how to allocate a limited budget when many comparisons are to be made in a multi-factor study. As a first step toward this goal the problem of allocating a sample to attain fixed (symmetric) precision requirements at minimum cost is considered.

Major emphasis has been placed upon linear models with interactions assumed to be negligible although the comparable situations where all interactions are assumed to be non-negligible have also been studied. The assumption of zero interaction is reasonable for some surveys, particularly those used in place of experiments. Such situations might arise because of the high cost or impossibility of experimentation. In particular, a test (or tests) for interaction may suggest that estimation be carried out under this assumption.

Some of the results obtained have suggested that selecting sample sizes proportional to the within classification standard deviations (or variances) is a poor procedure. Thus, the investigation with the "no interaction" model serves as a warning that "general" allocation principles are not general, and one must consider the population of interest and the comparisons to be made before embarking on a survey design. From some preliminary results, it is clear that substantial cost savings are possible by using optimal allocation with the selected model.

Dr. Sedransk has developed a sequential scheme to estimate differences between subgroup means with prescribed precision. It is assumed that the subgroups are not identifiable in advance of drawing a random sample from the population. Since this procedure requires one to know the subgroup variances, it is not entirely satisfactory. A modification is proposed for the case of unknown variances assuming homoscedasticity and normally distributed populations.

A conditional multi-stage procedure to estimate the mean from a normal population with unknown vari-

ance is suggested as an alternative to a two-stage procedure suggested by Stein in 1945. The "pilot" stage is used primarily to provide information about the mean, μ, and the size of the second sample. Sampling can terminate at each of several stages, and the estimate of variance used is always the one derived from the most recent stage of sampling. (Information about the mean is obtained from the entire sample.) Inferences are made conditional on the stage at which sampling is terminated; in particular, all inference is conditional on the estimates of variance from the previous stages.

Much of the distribution theory has been worked out, although the consequences of the procedure have not. This conditional procedure should reduce the chance that an unusually large sample size will be required. In addition, some advantages should accrue from the use of conditional rather than unconditional distributions.

Working on another aspect of the Bureau of the Census research project, Dr. Fuller conducted research on the small sample properties of post stratified estimators. This research will be continued during the coming year.

Evaluation of 1964 Census of Agriculture

The Survey Group is working on a research project with the United States Department of Commerce, Bureau of the Census, to assist the government in conducting a coverage check and related evaluation studies of the 1964 Census of Agriculture.

The coverage check is being conducted on a nationwide basis to include the canvassing of area segments and the completing of questionnaires for persons with agricultural activities in 1964, the subsequent matching of these cases against the 1964 census questionnaire and the eventual reconciliation, where necessary, of differences between data obtained through the two different types of questionnaires.

The Survey Group is preparing instructions for the use of the questionnaires and the field edit, and preparing training guides for the use of field supervisors. Mrs. Marjorie Mason and Harold Baker were in charge of recruiting, training and directing the work of interviewers in Iowa, Missouri and Kansas. Baker and Charles Graham also are providing technical assistance at the government's location in Jeffersonville, Indiana.

A similar cooperative project was completed five years ago.

Agricultural Estimates

The Survey Group is continuing a research project with the Research and Development Branch, Statistical Reporting Service, United States Department of Agriculture, on the prediction and objective estimation of grain sorghum yields and estimation of pasture yields. Principle personnel on the project were Norman Strand, Dr. Wayne Fuller and Harold Baker.

On the grain sorghum study, observations on plant and head characteristics and number of plants were obtained from plots on a sample of 50 farms in nine southwest counties. Each plot was visited five times between early August and early October. The data were used to provide information on optimum plot size and in the development of methods of making early season yield forecasts.

Baker continued research on the development of objective methods for determining pasture production. Plots were laid out in six Iowa State University pastures to furnish preliminary information of the practicability of the cage technique for estimating pasture production and harvest through grazing. Plots were relocated and clipped at two- and four-week intervals during the pasture season.

SCS, Sampling in Soil Surveys

Professor Norman Strand continues as leader of Agricultural Experiment Station Project 1312, Sampling in Soil Surveys. Under a cooperative agreement with the Soil Conservation Service, the Survey Group draws representative samples of land for determining conservation needs, in furtherance of the national program of soil and water resource conservation and use. Mrs. Marjorie Mason supervises work in this area.

During the year, tabulations were completed for an upper Mississippi River basin study involving Illinois, Iowa, Minnesota, Missouri and Wisconsin.

Work was started on the preparation of tables showing the total acres by land use, land capability units, resource area, watershed and county as determined from data collected in Colorado, Iowa, Missouri, North Dakota and South Dakota. This study of the Missouri River basin will be concluded next year with tabulation of data for Kansas, Montana, Nebraska and Wyoming. Similar work is being started on a special project in Michigan.

Data was collected in North Carolina to determine the total acres of cropland and pasture and the irrigation potential for counties within the coastal plain and Piedmont regions.

A special Ohio study involved tabulations of land use acreages by soil, slope, erosion, land capability units, major land resource area, watershed and county.

Work was started on a tax assessment study using Iowa SCS data. The project involves tabulation of land use by soil, slope and erosion for each county.

Programs to update SCS data have been continued. Data has been transferred from cards to tape so these data can be processed by electronic machines instead of the traditional card tabulating equipment.

Design of Experiments and Analysis of Data

Research on the design of experiments and analysis of data has continued under the direction of Dr. Oscar Kempthorne, supported by Agricultural Experiment Station Project 890.

Some preliminary work has been done on the χ^2 goodness of fit test, as applied to so-called continuous data. The literature contains various rules on the formation of classes to perform the test, a common one being that each cell expectation should be five.

The procedure examined in the present work is to partition the distribution whose goodness of fit is being tested into a number of equiprobable classes equal to the number of observations on the basis of

the probability integral of the distribution. As a consequence, with N observations there are N classes each with an expectation of unity. Some theoretical properties of the distribution of the resulting goodness of fit criterion, K, are obtained. On the basis of the first four moments, the distribution of K tends to the χ^2 distribution and the normal distribution. It is shown that this happens if the number of classes is at most of order N.

A small empirical test of the procedure has been made with 5,000 samples of size 10, 1,000 samples of size 20 and 500 samples of size 50 from a normal distribution. The mean and variance were estimated, and the classes obtained on the basis of the fitted distribution. The agreement of the empirical results with the theoretical form seemed to be quite remarkably good.

Some power calculations were made also. It is to be noted that the test obviously has asymptotic power against any alternative hypothesis. Work will continue in this area.

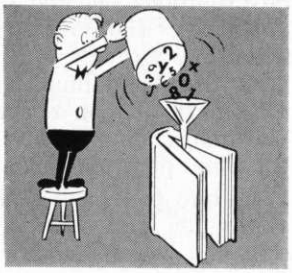
Much of the theory of estimation from so-called continuous distributions is based on the Method of Maximum Likelihood, which consists of maximizing the probability density of the observations. Actually this theory seems to be based on a fundamental error, in assuming that observations can be observed with indefinitely fine accuracy. As was obviously known to Fisher, the theory does not break down unless the distribution involved has sharp contact at either end. If this does happen, however, the theory gives a totally erroneous answer.

In the case of observations distributed uniformly over the range 0 to θ, for instance, the theory mentioned above tells us that the variance of the maximum likelihood estimate of θ, which is, in fact, the largest observed value, is inversely proportional to n^2. If, however, one examines what happens with a given interval of uncertainty of observation as must always be present, and which must be specified by the experimenter, one finds that the variance of the "proper" maximum likelihood estimate is inversely proportional to n, the sample size, for large n.

The consequences of not making the false assumption that observations are indefinitely precise, are being examined. The simple example given above tells us that the current theory is entirely erroneous, at least in the theory of large samples.

Publications and Professional Activities

Most of the research conducted by Statistical Laboratory staff members is reported in papers presented at professional meetings and in articles published in professional journals. In addition, the staff members take an active role in the operation of the professional societies of which they are members.



RECORD OF PUBLISHED RESEARCH

Articles published by staff members and graduate students during the past fiscal year are recorded on the following pages. When the research was conducted at Iowa State, but the author has since accepted a new position, his current location is listed in parenthesis after his name.

Some of these publications are included in the Statistical Laboratory's Reprint Series and copies are available upon request. These are indicated by an asterisk (*).

*__T. A. Bancroft__: "Analysis and Inference for Incompletely Specified Models Involving the Use of Preliminary Test(s) of Significance." Biometrics, 20:3, 427-442. September 1964. Journal Paper No. J-4848, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 169. Reprint Series No. 150, Statistical Laboratory, Iowa State University.

This paper discusses estimation and test(s) of hypotheses subsequent to preliminary test(s) of significance to determine the final form of a statistical-mathematical model. It assumes that a single sample is available for determining the final form of the statistical-mathematical model as well as the outcome of the subsequent inferences based on the model selected by preliminary test(s) of significance.

A number of examples are given from methods books in statistics in which use is made of preliminary test(s) of significance as an aid in determining model specification to be used in subsequent inferences based on a single sample. References are given to studies of bias and mean sequence error for the case of estimation after preliminary test(s) and for size and power for the case of test(s) after preliminary test(s).

A worked example, illustrating such inference procedures which have been designated "inference for incompletely specified models" by Bancroft, is given.

*__D. V. Sisson__ (Utah State University, Logan), T. A. Brindley and __T. A. Bancroft__: "Combining Biological Data from European Corn Borer Experiments Over Years." Iowa State Journal of Science, 39:4, 403-415. May 15, 1965. Journal Paper No. J-4977, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1193. Reprint Series No. 159, Statistical Laboratory, Iowa State University.

Since most research workers are aware of the possible dangers involved in drawing broad conclusions from the results of individual experiments, combining techniques are often required. The presence of heterogeneous error mean squares complicates the problem.

Data from European corn borer experiments were used to illustrate the procedures for split-split plot

designs. Two different combining techniques were employed. The first was an unweighted means analysis, the second a weighted means analysis where the weighting was applied at each of the three stages of the split design. The weights utilized were reciprocals of the variances of the means involved. This eliminated heterogeneity of error mean squares by reducing the error mean terms to unity, making the test involved χ^2 tests rather than F tests.

Both techniques yielded similar results, but the three-stage weighting procedure demonstrated the greatest utility.

Neeti R. Bohidar (C-E-I-R, Inc., Camp Dedrick, Maryland): "Derivation and Estimation of Variance and Covariance Components Associated with Covariance Between Relatives Under Sexlinked Transmission." Biometrics, 20:3, 505-521. September 1964.

This study has four chief objectives:

(1) To partition the total genotypic variances for male and female into their respective constituents,

(2) To construct the general structures of the covariances between two members of the same sex or different sexes with joint consideration of sexlinked and autosomal genes,

(3) To develop procedures for estimating the components of genetic variances and covariances from the analysis of variance, and

(4) To derive the heritability estimators under the assumption of both sexlinked and autosomal inheritance.

Probability arguments are used to derive the algebraic expressions for the covariances among relatives. The development refers to bisexual diploid organisms with males as the heterogametic sex.

F. B. Cady and D. D. Mason: "Comparison of Fertility Treatments in a Crop Rotation Experiment." Agronomy Journal, 56:476-479. September-October 1964.

Methods of analyzing corn yields from a fertility experiment conducted within the framework of a replicated two-year corn-soybean rotation in North Carolina are presented. Each crop of the rotation was continued for six years, resulting in two series and three cycles of the rotation. The analysis of variance presented is based on a model developed from examination of the structure of the rotation, i.e., utilizing the structural breakdown of the calendar years into series and cycles.

The errors involving the treatments are amalgamated due to the structure of the rotation experiment, i.e., due to the repetition of the treatments on the same plots during each cycle. The need to separate the constant portion of the error, a result of plot-to-plot differences, from the random year-to-year variation is shown.

Edward J. Carney, Leonard Z. Eggleton and Richard H. Forsythe: "The Effect of Reclaimed Shipping Cases on Egg Damage and Handling Efficiencies in the Egg Products Trade." Food Technology, 19:3, 91-94. 1965.

Traditionally shipping cases are reused until completely broken down, in the transmittal of shell eggs to breaking plants for processing. This study combined an experimental approach with traditional observational methods to determine the effect of case condition on processing time and product loss.

In analyzing the experimental results the analysis of covariance was used to eliminate the disturbing effect of bloody eggs. Estimates obtained from measuring time and product losses from experimental packs and from measured time elements in observational studies compared well.

Damaged cases increased transfer time 0.24 - 0.26 minutes per case by the two techniques. Damaged cases resulted in a greater product loss by 1.35 pounds per case. A study of a hypothetical (but typical) plant indicated a 25 to 30 percent replacement of cases at each use was optimum.

G. K. Benson, A. T. Cowie, **C. P. Cox**, S. J. Folley and Zena D. Hosking: "Relative Efficiency of Hexoestrol and Progesterone as Oily Solutions and as Crystalline Suspensions in Inducing Mammary Growth and Lactation in Early and Late Ovariectomized Goats." Journal of Endocrinology, 31: 157-164. 1965.

Hexoestrol (0.5 mg.) and progesterone (70 mg.) in oily solutions injected subcutaneously everyday over a period of 150 days were more effective in inducing mammary growth and lactation in ovariectomized goats than crystalline suspensions of hexoestrol (intramuscular injection every 50 days) and progesterone (intramuscular injection every 30 days) given during the same period and at the same total dosage.

Within treatments, the goats ovariectomized as adults, i.e., just before the hormone treatments were started, always had higher yields than goats ovariectomized in infancy. Standard statistical techniques were used.

A. T. Cowie, **C. P. Cox**, S. J. Folley, Zena D. Hosking and J. S. Tindal: "Relative Efficiency of Crystalline Suspensions of Hexoestrol and of Oestradiol Monobenzoate in Inducing Mammary Development and Lactation in the Goat; and Effects of Relaxin on Mammogenesis and Lactation." Journal of Endocrinology, 31:165-172. 1965.

Suspensions of oestradiol monobenzoate crystals (three intramuscular injections of 25 mg. at intervals of 50 days) in combination with suspensions of progesterone crystals (five injections of 2.1 g. at intervals of 30 days) were more effective in inducing mammary growth and lactation in ovariectomized goats than suspensions of hexoestrol and progesterone crystals administered at similar dose levels and intervals.

Daily injections of relaxin during the last 30 days of the above treatments reduced the milk yields apparently by inhibiting mammary growth. Standard statistical techniques were used.

H. T. David and **F. B. Cady**: "Calibration." Chapter 6, pp. 73-81, in *Methods of Soil Analysis, Part 1: Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling.* American Society of Agronomy, Inc., Madison, Wisconsin. 1965.

The statistical problem is to estimate and give a confidence interval for a "true" unknown X_0 corresponding to an observed Y_0. This estimate and confidence interval is based on Y_0 and the estimated calibration curve.

The estimation and construction of the confidence interval for the unknown X_0 are illustrated in terms of three examples typifying situations frequently met in practice. These examples are concerned with the case where an initial standardizing adjustment ensures a zero standard, i.e., ensures that the calibration curve passes through the origin. The first two refer to cases where the form of the calibrating curve is linear, but the first and second differ in the assumed structure of the experimental error. The third illustrates an application of an approximate method intended to deal with cases where linearity cannot be assumed.

***H. T. David**: "Order Statistics and Statistics of Structure (d)." Annals of Mathematical Statistics, 36:2, 897-906. June 1965. Reprint Series No. 162, Statistical Laboratory, Iowa State University.

Many goodness of fit statistics of structure (d) are asymptotically independent of the (d) structured ordered statistics. This fact can be used to construct tests that simultaneously test for c.d.f. shape and for outliers. For example, when the largest (d) structured observation is combined with the Kolmogorov-Smirov test, one obtains a three-sided acceptance region, sensitive to deviations of both types.

c. de Sousa Pinto and **H. T. David**: "Statistical Allocation of Soil Specimens to Eliminate Inaccuracies in Differential Molding Time." ASTM Proceedings, Vol. 64, 1068-1074. 1964.

Compression tests of stabilized soils can be influenced by molding time differentials when several specimens are molded from one batch. If specimen strength is linear with time, treatment comparisons will be free of time bias when the average molding serial number is the same for all treatments.

It is shown that this can be achieved, in the case of the usual triplicate determination per treatment, if and only if the number of treatments is odd, and systematic allocations are constructed for this case. Data from a pilot experiment with soil-cement mixtures illustrate the gains in accuracy possible under such allocations.

***Eugene Dayhoff** (Texas A. and M. University, College Station): "On the Equivalence of Polykays of the Second Degree and Σ's." Annals of Mathematical Statistics, 35:4, 1663-1672. December 1964. Reprint Series No. 153, Statistical Laboratory, Iowa State University.

Tukey extended the k-statistics of Fisher to a class of symmetric functions he named polykays. A generalization of Tukey's polykays was made by Hooke in reference to sampling from a two-way array or population. These generalized polykays were christened "bipolykays." Wilk and Kempthorne, working with certain structural patterns in the analysis of variance, introduced a set of functions denoted by Σ's. Zyskind extended and formally defined these Σ's for all "balanced" population structures and recognized the similarity of the Σ's in a two-way crossed structure and the bipolykays of degree two. He conjectured the equivalence of appropriately extended polykays with the whole set of Σ's for all balanced structures.

This paper is concerned with the extension of bipolykays of degree two and proving the equivalence of these and the Σ's. The bipolykays are first extended to "n-way polykays" then modified and defined for any arbitrary balanced n-factor structure. The equivalence of these generalized polykays of degree two and the Σ's is then shown.

***Carol E. Fuchs** and **H. T. David**: "Poisson Limits of Multivariate Run Distributions." The Annals of Mathematical Statistics, 36:1, 215-225. February 1965. Reprint Series No. 156, Statistical Laboratory, Iowa State University.

Consider n balls on a circle, colored white or black according to n mutually independent binomial trials. It is shown here that, when their expectations converge with n, (a) counts of runs of various lengths are asymptotically independent Poisson; (b) counts of certain configurations other than runs yield asymptotic correlated Poisson distributions; (c) counts of configurations with structure independent of n can be partitioned into equivalence classes, with asymptotic equivalence (equality with probability one) and asymptotic independence respectively within and among classes. It is also shown that (d) there cannot, essentially, exist configurations whose counts, asymptotically, are marginally, but not multivariate, Poisson.

C. Phillip Baumel and **Wayne A. Fuller**: "Estimates of the Productivity of Management Practices in Local Agribusiness Firms." Journal of Farm Economics, 46:4, 857-865. November 1964. Journal Paper No. J-4652, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1376.

In this study, the level of income and profit of a sample of firms was correlated with indices of management practices and of environment. The indices were included in a production function and a reduced form equation.

Management indices were constructed for areas of management defined as personnel and member relations, retail credit, inventory and wholesale merchandising, and strategic planning and sales management. Environmental indices were constructed for personal characteristics of the manager, competition and the board of directors.

The indices made a significant contribution to the explanation of both total income and return on fixed investment. The results suggest that it is feasible to construct measures of management behavior and to associate these measures with firm profitability.

*Wayne A. Fuller: "Stochastic Fertilizer Production Functions for Continuous Corn." Journal of Farm Economics, 47:1, 105-119. February 1965. Journal Paper No. J-4994, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1005. Reprint Series No. 158, Statistical Laboratory, Iowa State University.

The distributional properties of yield and profit for continuous corn production under nitrogen fertilization are investigated, and the mean and variance are estimated as functions of the rate of nitrogen fertilization.

It is noted that the variance of profit increases as the rate of fertilization increases. The current expected yield is shown to be a function of previous yield and fertilization history.

It is then demonstrated that information on previous yield outcomes may be used to specify a fertilization program which increases mean profit and/or reduces year-to-year variance in profit as compared to a fixed rate of application each year.

*W. A. Fuller and F. B. Cady: "Estimation of Asymptotic Rotation and Nitrogen Effects." Agronomy Journal, 57:3, 299-302. May-June 1965. Journal Paper No. J-4965, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1578. Reprint Series No. 160, Statistical Laboratory, Iowa State University.

Time rates of change in corn yields under nitrogen fertilizer in a long term experiment are estimated. The experiment includes four rotations, each containing two years of corn and from zero to three years of meadow. Three levels of nitrogen are applied to the corn in each rotation.

A model is presented which is characterized by the measuring of time in terms of rotation cycles and by the assumption of an exponential approach to a limiting value. This model appears consistent with the data. It was estimated that slightly over one-half of the effect of a rotation occurs with the first cycle. Large year-to-year variability in treatment effects and few cycles led to relatively large errors in this estimated rate.

A. W. Nordskog and Francis Giesbrecht (Research Triangle Institute, Durham, North Carolina): "Regression in Egg Production When Selection Is Relaxed." Genetics, September 1964.

This paper presented the results of some analyses of some data from a seven-year experiment designed to study the consequences of relaxed selection in three commercial strains of chickens. It was found that even if one assumed that the population had reached a plateau for egg production, i.e., did not respond to selection, then the population would decline when selection is relaxed. There was also some evidence that the rate of decline was non-linear.

*F. Giesbrecht (Research Triangle Institute, Durham, North Carolina) and O. Kempthorne: "Examination of a Repeat Mating Design for Estimating Environmental and Genetic Trends." Biometrics, 21:1, 63-85. March 1965. Journal Paper No. J-4868, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1448. Reprint Series No. 163, Statistical Laboratory, Iowa State University.

The general purpose of any breeding program is to produce some change in the genetic structure of the population in question. The use of control populations in which attempts are made to prevent any changes in the genetic structure indicates the potential value of devices for measuring progress due to selection.

The experimental design discussed in this paper provides three measures of genetic changes. All three depend essentially on the use of matings which are repeated identically during two successive breeding seasons.

The first of these measures the difference between the means of two groups of birds of different generations but reared in the same year. The second method measures a combination of changes in genetic and joint maternal-year effects and is, therefore, of doubtful value. The third measures the regression of response due to selection on years. The last method has the disadvantage that the proper error is difficult, though not impossible, to estimate. The number of degrees of freedom available for this estimate is also very limited.

*J. L. Gill (Michigan State University, East Lansing): "Effects of Finite Size on Selection Advance in Simulated Genetic Populations." Australian Journal of Biological Sciences, 18:3, 599-617. June 1965. Journal Paper No. J-4804, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1508. Reprint Series No. 166, Statistical Laboratory, Iowa State University.

The design and analysis of an investigation of selection in simulated genetic populations is discussed. The long-range objectives and specification of parameters and models are outlined, and certain mechanics of simulation of genetic systems are included, some of which may be of general application to Monte Carlo investigations.

The results from selection in small simulated populations under nine different models of gene action are discussed with respect to the effects of population size on inbreeding depression and the random drift of gene frequency.

*Dewey L. Harris (DeKalb Agricultural Association, Inc., Sycamore, Illinois): "Biometrical Parameters of Self-Fertilizing Diploid Populations." Genetics, 50:5, 931-956. November 1964. Journal Paper No. J-4749, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1448. Reprint Series No. 151, Statistical Laboratory, Iowa State University.

The probabilistic aspects of genetic populations obtained by continued selfing from an arbitrary initial population are investigated. This study suggests a system for expressing relevant genotypic means and covariances for a quantitative trait as a function of a more basic set of parameters. After some simplifying

assumptions, the formulae for a sub-population derived from a single individual in the initial generation are found to be

$$\mu^{k} = \sum_{x=0}^{n} \frac{1}{2^{kx}} (\delta^{x})$$

and

$$\mathrm{Cov}(k;r,s) = \sum_{x_{12}=0}^{n} \sum_{w=0}^{n-x_{12}} \sum_{x_1=x_{12}}^{n-w} \sum_{x_2=x_{12}}^{n-w-(x_1-x_{12})} \frac{2^{kx_{12}-0^{w}}}{2^{rx_1+sx_2}} \left(1 - \frac{1}{2^{k}}\right)^{w} Q^{x_{12}w}_{x_1x_2}$$

where

$\mu^{(k)}$ is the genotypic mean in generation k (the original individual occurred in generation zero and the generations are numbered consecutively),

$\mathrm{Cov}(k;r,s)$ is the genotypic covariance between the r-th generation progeny means of generation k individuals with the generation s progeny means of the same generation k individuals,

n is the total number of loci influencing the trait under consideration,

and (δ^{x}) and $Q^{x_{12}w}_{x_1x_2}$ are functions of the genotypic values involved and are the basic parameters of these formulae.

Similar parametrizations exist for the over-all population. Study of these formulae suggest several interesting and informative aspects of the relationships among the means and among the covariances.

***Dewey L. Harris** (DeKalb Agricultural Association, Inc., Sycamore, Illinois): "Genotypic Covariances Between Inbred Relatives." Genetics, 50:6, 1319-1348. December 1964. Journal Paper No. J-4796, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1505. Reprint Series No. 152, Statistical Laboratory, Iowa State University.

The probabilistic aspects of the Mendelian mechanism is considered so as to obtain a basic parametrization for the covariances between genotypic values for quantitative genetic traits in pairs of relatives occurring in inbred populations derived from random mating populations and for the variance of genotypic values of inbred individuals. The results are quite general and encompass the results of several previous workers.

The results suggest a set of eight values for the complete description of the genetic relationship between two inbred relatives, and a systematic procedure is suggested for obtaining these values from pedigrees indicating the relationship.

***H. O. Hartley** (Texas A. and M. University, College Station): "Exact Confidence Regions for the Parameters in Non-Linear Regression Laws." Biometrika, 51:3 and 4, 347-353. December 1964. Reprint Series No. 155, Statistical Laboratory, Iowa State University.

In this study the authors construct exact confidence regions for θ in the general case of a non-linear regression law such as:

$$y_t = f(x_t, \theta) + e_t \quad (t = 1, 2, \ldots, N),$$

where θ is an unknown m-vector of parameters θ_i.

If the sum of squares e'e is decomposed into two quadratic forms Reg(e) and Res(e) of rank m and N—m respectively, then $\mathrm{Reg}\,(y_t - f(x_t, \theta))/\mathrm{Res}\,(y_t - f(x_t, \theta)) \leq \frac{m}{N-m}$ F represents an exact confidence region for θ with confidence coefficient $(1-\alpha)$ if F is the upper $100\alpha\%$ point of the F distribution.

Much of the paper is concerned with the choice of Reg(e). It begins by assembling certain well-known results from linear least-squares theory, studies the exact confidence regions in non-linear estimation, and develops approximate linearization of the regression law by Lagrangian interpolation. Finally, comparison is made with alternative methods of constructing confidence regions.

***H. O. Hartley** (Texas A. and M. University, College Station) and Aaron Booker: "Nonlinear Least Squares Estimation." Annals of Mathematical Statistics, 36:2, 638-650. April 1965. Reprint Series No. 165, Statistical Laboratory, Iowa State University.

This paper deals with the point estimation of the m-parameter vector θ in the non-linear regression law of the form:

(1) $y_t = f(x_t, \theta) + e_t \quad (t = 1, 2, \ldots, N)$

It develops an iterative method of solution of least squares equations which has the following properties: (a) the computational procedure is convergent for finite N; and (b) the resulting estimators are asymptotically 100 percent efficient as N approaches infinity.

Assuming $N = m \times k$, the data lines are grouped in m groups of k observations each and (1) averaged to obtain the "average law":

(2) $y_h = f_h(x, 0) + e_t \quad (h = 1, 2, \ldots, m)$, where h is the group index.

The least squares estimator in (2), say 0, is shown to be a consistent estimator of 0 and the modified Gauss Newton method shown to converge for its computation. This consistent estimator 0 is then used as a starting point for a maximum likelihood iteration on (1) which is proved to yield 100 percent efficient estimators either after the first cycle or at termination.

Although the theoretical development is oriented toward the specific goals set forth in this paper, certain results are proved in a somewhat more general form. Some of the theory expressed will be seen to correspond to well known theorems on stochastic limits which have to be reproved because of certain modifications which the authors require.

E. L. Nichols, **D. K. Hotchkiss** and S. L. Balloun: "Effect of Age and Body Weight on the Systolic Blood Pressure of the Growing Chicken." Poultry Science, XLII:6, 1465-1466. Journal Paper No. J-4657, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1062.

The relationship of systolic blood pressure of growing cockerels (Y) to changes in age (X_1) and weight gain (X_2) was examined as a multiple regression relationship. The high correlation ($r = .97$) between age and weight gain in these data necessitated the inspection of each regression separately.

These data did not allow sufficient independent fluctuation of age and weight gain to evaluate either factor after adjustment for the other was made.

Carolyn Boatman, **Donald K. Hotchkiss** and Earl G. Hammond: "Effect of Season and Stage of Lactation on Certain Polyunsaturated Fatty Acids of Milk Fat." Journal of Dairy Science, XLVIII:1, 34-37. January 1965. Journal Paper No. J-4934, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1517.

Milk samples from individual cows selected to represent various stages of lactation for each month of the year were analyzed by the alkali isomerization-spectrophotometric and lipoxidase procedures for their polyunsaturated fatty acid content.

Parameters for seasonal effects, stage of lactation effects and cow effects were estimated using a least-squares analysis. The effect of these parameters on the several fatty acid constituents were reported and a seasonal and stage of lactation curve, adjusted for cow differences, was presented.

Marjorie M. McKinley, Ivan L. Town, Young Sook Kim and **Donald K. Hotchkiss**: "Methods of Preparing Turkey for Quantity Food Service." Journal of Home Economics, 57:1, 42-48. January 1965. Journal Paper No. J-4785, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1338.

Three experiments designed to control the labor time and yield of cooked turkey meat were conducted as randomized complete block experiments. These studies were combined and comparisons among the various treatments were made using Duncan's multiple range test.

The results of this study were used to make recommendations to users of turkey in quantity food service.

J. W. Rust, N. L. Jacobson, A. D. McGilliard and **D. K. Hotchkiss**: "Supplementation of Dairy Calf Diets with Enzymes. II. Effect on Nutrient Utilization and on Composition of Rumen Fluid." Journal of Animal Science, 24:1, 156-160. February 1965. Journal Paper No. J-4691, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1324.

The changes in several rumen fluid constituents over time after feeding and the apparent nitrogen and energy digestibility of six-month-old calves that were fed hay and concentrate diets with and without supplemental enzyme concentrate were measured in this study. The complete set of data were used to get an estimate of experimental error after which planned treatment contrasts were made. The results are outlined in the paper.

J. L. Morrill, N. L. Jacobson, A. D. McGilliard and **D. K. Hotchkiss**: "Use of a Re-entrant Ileal Fistula to Study Carbohydrate Utilization by the Young Bovine." The Journal of Nutrition, 85:4, 429-437. April 1965. Journal Paper No. J-4937, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1324.

Four three-week-old calves were fitted with a re-entrant ileal fistula and fed milk, or milk plus added sucrose or starch, at various ages up to 4.5 months. Ileal and fecal samples were taken at intervals after feeding the test diet to observe the extent of carbohydrate utilization before and after the ileal fistula.

The resulting data were subjected to least-squares analysis to detect treatment differences. A large calf by treatment interaction, a result of the mechanical placement of the fistula, necessitated a graphical interpretation of the data from this study. Some statistical treatment of segments of the data assisted the researcher in his interpretation of the data as was reported in this paper.

Agnes Frances Carlin, Donna M. Bloemer and **Donald K. Hotchkiss**: "Relation of Oven Temperature and Final Internal Temperature to Quality of Pork Loin Roasts." Journal of Home Economics, 57.6, 442-446. June 1965. Journal Paper No. J-5035, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1401.

Rib and loin pork cuts were used to compare the cooking and eating characteristics of 4.5-pound roasts cooked to final internal temperatures of 170 and 185 degrees Fahrenheit in ovens heated to 300, 325, 350 or 375 degrees Fahrenheit.

The experiment was set up as a split plot design using internal temperatures as the sub plot treatment with oven temperatures administered using an incomplete block to accommodate the taste panel aspects of the study.

The results of the study are summarized in the article.

***B. K. Kale**: "A Note on the Loss of Information Due to Grouping of Observations." Biometrika, 51:3 and 4, 495-497. December 1964. Reprint Series No. 154, Statistical Laboratory, Iowa State University.

X is a r.v. with p.d.f., $f(x, \theta)$, $\theta \epsilon \Omega$. Let $\{E_i\}_{i=0}^{n+1}$ be a partition of R_1 into disjoint intervals. Let X_g be the corresponding r.v. with multinomial distribution $\{\pi_i(\theta)\}_{i=0}^{n+1}$ where $\pi_i(\theta) = P[X_g \epsilon E_i/\theta]$. Let $I(\theta, \theta_0)$ and $I_g(\theta, \theta_0)$ be the amount of discriminatory information supplied by the r.v., X and X_g respectively. Let G be the set of all groupings and $\{X_g, g \epsilon G\}$ be the set of all multinomial distributions

with finite number of cells. G is then a directed set with respect to the partial order relation of "refinement" and $I_g(\theta, \theta_0)$ is a net or generalized sequence. This paper proves that $\underset{g \epsilon G}{\text{lub}}\ I_g(\theta, \theta_0) = I(\theta, \theta_0)$ and the generalized sequence $I_g(\theta, \theta_0)$ converges (in the sense of Moore-Smith) to $I(\theta, \theta_0)$. Similar results about Fisher's information index $I(\theta_0)$ are obtained. Applications of these results for estimation using grouped data are indicated.

Oscar Kempthorne, **Theodore A. Bancroft**, John W. Gowen and Jay L. Lush, editors: *Statistics and Mathematics in Biology.* Hafner Publishing Company, New York. 1954, reprinted 1964.

This book synthesizes the concepts and methods of statistics and mathematics. It's suitable for use in a seminar course in biometrics or biostatistics, as well as for use as a reference book for research and consulting workers in the biological sciences and statistics.

The book is essentially a summation of the material presented at the Biostatistics Conference held at Iowa State in the summer of 1952 under the joint auspices of faculty in biology, agriculture and statistics at the university, and Biometric Society (Eastern North American Region). The text was compiled under the editorial direction of the program committee for the conference: O. Kempthorne, chairman, T. A. Bancroft, John Gowen (then head of the Genetics Department) and Jay L. Lush (professor in the Department of Animal Science), all of Iowa State.

A more complete view of the scope of the book can be obtained from the following list of chapter headings and authors:

Part I – General Biometrical Principles and Procedures

George W. Snedecor: Biometry, its makers and concepts.
Sewall Wright: The interpretation of multivariate systems.
John W. Tukey: Causation, regression, and path analysis.
Harold Hotelling: Multivariate analysis.
A. M. Dutton: Application of some multivariate analysis techniques to data from radiation experiments.
Edgar Anderson: Efficient and inefficient methods of measuring specific differences.
Stanley L. Isaacson: Problems in classifying populations.
K. R. Nair: The fitting of growth curves.
Warren H. Leonard: Experimental designs in agronomy.
Walter T. Federer: Survey of experimental design.
M. H. Quenouille: The experimental utilization of identical twins, clones, and other genetic subgroups.
C. West Churchman: The philosophy of experimentation.

Part II – Changes in Population Number

Thomas Park: Competition: An experimental and statistical study.
Chin Long Chiang: Competition and other interactions between species.
Francis J. Ryan: Analysis of populations of mutating bacteria.

Part III – Estimation of Populations

R. J. Jessen: General methodology in sampling human populations.
Harold F. Dorn: Some problems in sampling human populations.
S. R. Gevorkiantz: Problems in forest inventory: From the forester's point of view.
Austin A. Hasel: Problems in forest inventory: From the statistical point of view.
Leslie W. Scattergood: Estimating fish and wildlife populations: A survey of methods.
D. B. DeLury: On the assumptions underlying estimates of mobile populations.
Geoffrey Beall: Data in binomial or near-binomial distribution: With particular application to problems in entomological research.
Pascal K. Whelpton and Halvor Gille: The growth of human population.

Part IV – Determination of Biological Response

Lloyd C. Miller: The quantal response in toxicity tests.
Jerome Cornfield: Measurements and comparison of toxicities: The quantal response.
C. I. Bliss: Insecticidal assays.
Peter B. Dews and Joseph Berkson: On the error of bioassay with quantal response.
George F. Stewart: Analytical sensory tests for food products.
J. W. Hopkins: Some statistical aspects of flavor and aroma testing.
J. K. Loosli: Determination of the nutritional requirements of dairy animals and swine.
Paul G. Homeyer: Some problems of technique and design in animal feeding experiments.
Clyde Stormont: Research with cattle twins.
J. P. Scott: Biomathematical problems in animal behavior.

Part V – Genetical Analysis of Populations

Philip Levine: Gene frequencies in nonexperimental populations.
C. W. Cotterman: Estimation of gene frequencies in nonexperimental populations.
James V. Neel: A description of studies on the potential genetic effects of the atomic bombs in Japan. I. Organizational aspects.
William J. Schull: A description of studies on the potential genetic effects of the atomic bombs in Japan. II. Analytical problems.
Ernest C. Pollard: Radiation effects on the functioning of body cells.
John W. Gowen: Effects of X-rays of different wave lengths on viruses.
Herbert H. Kramer: Recombination in selfed chromosome interchange heterozygotes.
Bruce Griffing: Contributions of genotypic and environmental effects to earliness of tomato fruiting.
Jay L. Lush: Breeding structure of populations. I. General considerations.
James F. Crow: Breeding structure of populations. II. Effective population number.
Cecilie Leuchtenberger: The nucleoproteins in cell growth and division.

***R. J. Buehler** (University of Minnesota, Minneapolis), **B. V. Shah** (Operations Research Group, Bhadra, Ahmedabad, India) and **Oscar Kempthorne**: "Methods of Parallel Tangents." Chemical Engineering Progress Symposium Series, 60:50. 1964. Reprint Series No. 149, Statistical Laboratory, Iowa State University.

A well-known procedure for determining the point $(x_1, x_2, \ldots, x_n)$ at which a function $\phi(x_1, x_2, \ldots, x_n)$ F is a minimum, is the method of steepest descent. A few properties of this method are described.

In general the method is poor because of its asymptotic convergence even in the ideal case of ϕ being quadratic in the x's and measured without error. Some other procedures are described briefly.

The class of methods called PARTAN, based on the idea of parallelism of tangents being preserved under affine transformation, is described. Some properties of the class of methods are presented and discussed.

Oscar Kempthorne and R. R. Allmaras: "Errors of Observation." Chapter 1, pp. 1-23, in *Methods of Soil Analysis, Part 1: Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling.* American Society of Agronomy, Inc., Madison, Wisconsin. 1965. Journal Paper No. J-4633, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 890.

This paper gives an elementary account of errors of observation. A rough classification of errors is given and the different types of error discussed.

Elementary ideas of characterization of variability and the estimation of precision of observations are presented. The precision of derived observations is discussed briefly.

*Akio Kudô and Taira Katayama: "On So-Called Secondary Association in Rice Plants II. Statistical Analysis." Japanese Journal of Genetics, 40:1, 33-44. 1965. Reprint Series No. 164, Statistical Laboratory, Iowa State University.

This work is concerned with the controversy about the origin of rice plants, especially with the basic number of chromosomes in rice proposed by K. Sakai in 1935.

In order to analyze the data obtained by T. Katayama, three types of randomness were introduced: general random association, linear random association and circular random association, with the object of examining whether or not the derivation from randomness supports the hypothesis proposed by Sakai.

The result of the analysis revealed the highly non-random nature of the secondary association of rice plants, but the derivations do not support Sakai's hypothesis that the basic number of chromosomes in rice is five.

J. N. K. Rao (Texas A. and M. University, College Station): "Unbiased Ratio and Regression Estimators in Multi-stage Sampling." Journal of the Indian Society of Agricultural Statistics, XVI:2, 175-188. 1964.

In recent years, considerable attention has been given in the literature to the construction of unbiased ratio and regression estimators, since the classical ratio and regression estimators are biased.

Mickey (Journal of the American Statistical Association, 1959) has given a method of constructing a broad class of unbiased ratio and regression estimators in simple random sampling which includes the well known Hartley-Ross unbiased ratio estimator. However, since in practice multi-stage sampling is often employed, it seems necessary to extend Mickey's method to multi-stage designs.

In this paper Mickey's method is extended to two-stage sampling, and two different classes of 'combined' unbiased ratio and regression estimators are constructed. The estimators in class 1 depend on the sum of the population totals x_i of the n primaries selected in the sample, where x_i is the i^{th} primary population totals of the supplementary variate 'x'. (This sum may not be known in practice.) The estimators in class 2 depend only on the overall population mean $\bar{x}$ of the variate 'x', so that the estimators in class 2 may become more useful in practice.

A simple method of variance estimation, similar to that of Goodman and Hartley (Journal of the American Statistical Association, 1958) for the unbiased ratio estimator in simple random sampling, is proposed.

*G. R. Seth and **J. N. K. Rao** (Texas A. and M. University, College Station): "On the Comparison Between Simple Random Sampling with and without Replacement." Sankhyā: The Indian Journal of Statistics, Series A, 26:1, 85-86. 1964. Reprint Series No. 161, Statistical Laboratory, Iowa State University.

In this note, a comparison is made between simple random sampling with and without replacement.

It is shown that, for the same expected cost, simple random sampling without replacement provides an estimator of the population mean or total with a variance smaller than the variance of estimates based on distinct units in with replacement sampling, the cost being proportional to the number of distinct units in the sample.

Elaine V. Houck, D. Bruce Gardner and **Donna Ruhl**: "Effects of Auditory and Visual Pretraining on Performance in a Tactile Discrimination Task." Perceptual and Motor Skills, 20, 1057-1063. 1965. Journal Paper No. J-4949, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1595.

Three groups of preschool children, ages 45 to 60 months, were compared for performance in a tactile discrimination task. Group A received auditory pretraining; group V received visual pretraining; and group C received only familiarization with the room and apparatus.

The basis of discrimination in the three modalities (vision, audition, and touch) was "one" versus "two." The V subjects had to discriminate between one and two circles; the A subjects had to discriminate between one and two buzzer sounds; and all subjects had to discriminate between one and two cubes using only touch.

For this specific tactile task, it was concluded that (1) both auditory and visual pretraining facilitate performance in the tactile task, (2) visual pretraining is more effective than auditory pretraining in facilitating performance in the tactile task, and (3) age of the subject is a significant covariate on performance in the tactile task.

The statistical analysis employed was a covariance analysis with unequal numbers of observations per treatment and Duncan's multiple range test adjusted for covariance. This analysis is more complicated than those typically done in child development and psychology research, and it is hoped that readers in these fields will become aware of the covariance method and some of its uses through this paper.

Frederick G. Brown and **Leroy Wolins**: "An Empirical Evaluation of the American College Testing Pro-

gram." Personnel and Guidance Journal, 43, 451-456. January 1965.

This paper summarizes research with the American College Testing Program (ACT) at one university over a three-year period. Subjects were 4,597 freshmen divided into five groups by college and sex.

General positive conclusions were that the ACT (a) is a good measure of general scholastic aptitude, (b) has definite administrative advantages to the university by providing scores prior to a student's admission, and (c) aids prediction for certain subgroups of students.

However (a) the tests are probably not difficult enough and have a restricted range of scores, (b) the battery is inefficient in terms of student time, and (c) the subtests do not have differential validity.

*Leroy Wolins and Robert Perloff: "The Factorial Composition of AGCT 'Subtests' along with College Aptitude Items and High School Grades." Educational and Psychological Measurement, 25:1, 73-78. Spring 1965. Reprint Series No. 157, Statistical Laboratory, Iowa State University.

As a major conclusion to be drawn from this study, the investigators would suggest that failure of one of the reading subtests to load on its group factor and failure of one of the data interpretation subtests to load on its group factor indicate that the variance explained by these two group factors is due to the intrinsic difficulty of the reading passage or graph rather than to the difficulty of the items referring to the reading passage or graph.

If the items are complex and the chart or reading passage is straightforward, only the General factor will be measured, but if the graph or reading passage is difficult or complex, the appropriate group factor will be measured as well.

Robert Perloff and **Leroy Wolins**: "Item Difficulty as a Function of Perceived Item Directions." Educational and Psychological Measurement, 25:1, 79-85. Spring 1965.

In this study an effort was made to determine the effect of a set of incorrectly perceived directions upon responses to similar verbal reasoning items in adjacent item blocks.

A possible positioning effect was observed when a college aptitude subtest of verbal reasoning was administered to a sample of college freshmen women. Approximately 75 percent of the subjects were confronted with the synonyms item block before the opposites item block. An examination of item responses suggested the possibility that many of the subjects were answering the opposites items retaining erroneously the directions from the preceding item block, synonyms.

In subsequent administrations of the subtest, to a sample of college men selected randomly from a national sample and to a sample of high school senior males, the opposites item block preceded the synonyms item block, operational constraints precluding a counterbalanced design for these two samples.

The results indicated that average item difficulties show clearly that while synonyms were intrinsically more difficult than the opposites regardless of position in the subtest, they were significantly more difficult when preceded by opposites than when followed by opposites.

Reasons for the positioning effect were suggested, along with an indication of possible ways in which the effect can be reduced or eliminated.

Edwin C. Lewis, **Leroy Wolins** and John Hogan: "Interest and Ability Correlates of Graduation and Attrition in a College of Engineering." American Educational Research Journal, 2, 63-74. March 1965.

Many psychological tests routinely used in counseling college students about vocational choice use normative data based on performance of people who are presently engaged in a particular vocation. In particular the engineering key for the Strong Vocational Interest Blank (SVIB) is derived from responses of professional engineers to the questions in that inventory. If an entering college student responds to these questions like professional engineers do, the counselor invites the student to conclude he is interested in engineering.

The sample used in this study consisted of engineering students from Iowa State University. The particular kind of engineering: mechanical, electrical, architectural, etc.; and graduation vs. attrition in each area were treated as independent variables. Scores on various subtests of the SVIB, achievement test scores, and high school grade point average were treated as dependent variables.

The results indicated highly reliable differences in responses to SVIB items for graduates in different curricula in engineering. For example, the architectural engineer responds to the SVIB more like an artist than the average engineer. The cognitive measures, achievement test scores and college grades were somewhat related to curricula, but were more indicative of graduation vs. attrition. The SVIB variables were not clearly related to graduation vs. attrition independently of cognitive variables.

G. Zyskind, **O. Kempthorne**, **R. F. White** (Smith, Kline and French Laboratories, Philadelphia, Pennsylvania), **E. E. Dayhoff** (Texas A. and M. University, College Station) and **T. E. Doerfler**: *Research on Analysis of Variance and Related Topics*, Aerospace Research Laboratories, Office of Aerospace Research, United States Air Force, Wright-Patterson Air Force Base, Ohio. November 1964.

The research described in this report is directed toward understanding of linear models and the analysis of variance with regard to experimentation. Previous research was based on explicit use of the design of the experiment and this has continued to provide the background for the development.

The particular topics examined are closely related, in that they are concerned with the consequences of the way of performing experiments with regard to the interpretation of the analysis of variance and tests of significance and of hypotheses. The theoretical basis is then the random sampling of populations of possible

levels of factors and the random association of levels of different factors, which occurs in the physical randomization usually performed. Closely related to the whole area is the use of linear models, and considerable attention has been given to the general study of these.

Chapter I gives a general outline of topics covered in the report. Chapter II gives a detailed account of the randomization consequences in a generalization of the balanced incomplete block design. Chapter III attempts a unified formulation of experimental structures and discusses variance analysis in the general experiment.

Chapter IV introduces generalized polykays and discusses their application to the obtaining of variances and covariances of components of variation. Chapter V discusses and relates various topics in linear models. Chapter VI discusses the size and power of certain tests under experimental randomization.

Book Review

What Do Statistics Show? by F. R. Oliver. London, England: Hodder and Stoughton, Limited. 1964. Pp. 157 21s. Reviewed in the Journal of the American Statistical Association, 60:309, 386-387, March 1965, by T. A. Bancroft.

ABSTRACTS OF THESES

Rodney Peter Basson: "On Unbiased Estimation in Variance Component Models." Ph.D. thesis. Iowa State University Library. May 1965.

This study considers unbiased estimation of variance components and regression parameters in the model represented by

$$y = \sum_{i=0}^{r} X_i\gamma_i + \sum_{i=r+1}^{k+1} X_i\beta_i$$

where γ_i's are fixed unknown vector parameters, β_i's are random vectors with expectation $E(\beta_i)$ equal to zero, and $E(\beta_i\beta_j') = 0 (i \neq j)$, and where X_i's are known fixed matrices of constants, $X_{k+1} = I$ and $E(\beta_{k+1}\beta_{k+1}') = I\sigma^2_{k+1}$.

Usually the assumption $(E(\beta_i\beta_i') = I\sigma_i^2$ $(i = 1, \ldots, k)$ is made, but some consideration is also given to the alternative assumption, $E(\beta_i\beta_i') = (a_i/b_i)$ where (a_i/b_i) is a matrix with elements a_i on the diagonal and all off diagonal elements equal to b_i. A model representation is defined to be balanced$_2$ if

$$X_iX_i'X_jX_j' = X_jX_j'X_iX_i' \quad (i \neq j, i, j=0, \ldots, k+1).$$

A representation that is not balanced$_2$ is unbalanced.

Completeness of the sufficient set of statistics is established by a restriction on the number of roots of $V = E(yy') - E(y)\ E(y')$. Several theorems, on the minimum variance properties under normality of Model I type A.o.V. estimators for variance components, and simple least squares estimators of estimable functions of regression parameters for balanced mixed models, are proved. Certain optimality properties for the same estimators, when the normality assumption is replaced by a less stringent condition, are obtained.

Many design situations, some common and others less so, do not satisfy the conditions of balance$_2$. Generally, even under an assumption of normality, the minimal sufficient set of statistics in unbalanced situations is not complete. It is not known whether U.M.V. estimators exist in these cases, and if they do, how to proceed to obtain them. Since here the assumption of normality cannot apparently be profitably used, and later removed, we favor obtaining alternative estimators directly, and comparing them at different points of the parameter space by means of the variances of each variance component estimator.

A substantial part of the thesis gives consideration to the "least squares" method of estimation in unbalanced cases. We present a transformation procedure, which is actually a single degree of freedom breakdown of sums of squares, and which in random models provides one means of finding variances of variance component estimators. The procedure suggests theoretically, at least, an alternative way of weighting single degree of freedom sums of squares to find estimators with smaller variance than those given by simple least squares.

A general variance formula for variance component estimators, when normality is assumed, and when it is not, for both random and mixed models, is obtained. The covariance formula between two least squares estimators of variance components is also presented, thus enabling one to set up theoretical measures of the efficiency of the least squares method for potential use against alternative types of estimators.

Charles Edwin Cress: "Theoretical and Simulated Selection Studies Based on Progeny Performance with Special Reference to Reciprocal Recurrent Selection." Ph.D. thesis. Iowa State University Library. May 1965.

This study examines theoretically and by simulation, certain aspects of recurrent selection based on progeny tests. The breeding method under critical examination was reciprocal recurrent selection (RRS). The relationship between two theories of RRS was studied and the theories were shown to be equivalent in indicating that progress is based on additive genetic variances in test cross progeny. Selection for nonadditive effects in the hybrid of the two populations was based on unequal selection pressure on the two populations.

A set of comparisons of rates of progress was made among all possible testing-mating systems utilizing two populations. RRS was used as a basis of comparison since this method was reported to have maximum potential and a good rate of progress under a wide range of conditions. These comparisons were expressed for an arbitrary number of alleles at a single locus in matrix notation.

Explicit results were obtained and meaningful interpretations were possible for two alleles per locus. The progeny testing system found most competitive with RRS was termed "within population selection" (WPS). The tester in WPS was the population under selection. It was found that for the case of partial or

complete dominance WPS had a more rapid rate of progress than RRS when $a_1+b_1 > 1.0$, where a_1 and b_1 are the frequencies of the dominant alleles in the two populations. In the overdominant case, WPS has a faster rate than RRS only when $a_1+b_1 > 1.0$, but less than two times the equilibrium gene frequency.

The simulation studies were conducted by the Monte Carlo method for the completely dominant and purely overdominant models. A bisexual organism with two alleles at each of 40 independently segregating loci was simulated. RRS and two modifications of RRS were performed for 20 cycles at a number of starting conditions. It was concluded that genetic divergence was not a sound basis for selecting populations for RRS. Increase in the means of the recurrent populations cannot be used as evidence for a predominance of partially or completely dominant gene action.

Two modifications were found to be important to improve genetic potential and rate of progress for all types of recurrent selection utilizing progeny testing:

1. A synthetic variety should be made from all material which is to be entered into a recurrent selection program.
2. One generation of selfing (or other inbreeding) should precede the test crosses in each cycle.

Discussion was presented which relates the ultimate usage of selected populations to the choice of a breeding system. The relation of gene frequency differences between two populations to the expression of heterosis was developed mathematically. The implications of these results were discussed.

Ahmed Hassan El Mawaziny: "Chi-square Distribution Theory with Applications to Reliability Problems." Ph.D. thesis. Iowa State University Library. May 1965.

This study presents some theoretical results which can be applied to the problem of confidence limits for the reliability of series systems of k dissimilar components having exponential failure laws.

An exact finite expression for the density function of the sum of positively weighted chi-square variates with even number of degrees of freedom is given. This result is applied to obtain "fiducial" limits for the mean life (ϕ^{-1}) of the series system by assuming that ordinary distribution theory applies to the fiducial distribution.

Another approach to the estimation of the parameter ϕ is based on the theory of exponential families. A conditional distribution which arises from independent gamma variates is considered, and used for inference about the parameter ϕ.

The large sample approximation to the problem is also considered, and three different asymptotic results are obtained. The "derived fiducial" asymptotic distribution of the parameter ϕ is shown to be the same as the standard large sample solution based on the maximum likelihood estimator. The other two asymptotic results are based on the asymptotic behavior of the conditional distribution mentioned earlier. These three asymptotic results are compared and are used to set approximate "fiducial" limits for ϕ.

Numerical comparisons are made with some earlier results, including a related binomial model.

Edmund L. Fuller, Jr.: "Robustness of the Maximum Likelihood Estimation Procedure in Factor Analysis." M.S. thesis. Iowa State University Library. February 1965.

In order to investigate the robustness of Lawley's maximum likelihood estimation procedure, Monte Carlo methods were used. The assumption of normally distributed common and specific factors as well as the assumption of independence of the specific factors were considered.

The basic model of interest was one in which five variables were constructed using two common factors and five specific factors. Six replicates of the model, differing only in the coefficients of the factors, were investigated. The factors were represented by variates drawn from the following distributions: (1) the uniform distribution, (2) the normal distribution, (3) a truncated normal distribution, (4) a modified t distribution, (5) a triangular distribution, and (6) a bi-modal distribution. In the case of dependency of the specific factors, the variates were drawn from a standardized bi-variate normal distribution.

The thesis presents the synthesis of the artificial samples, formation of the variance-covariance matrices, computation of the maximum likelihood estimates, and evaluation of the results for each distribution within each of the six replicates.

With the exception of the dependency of specific factors, the maximum likelihood estimation procedure is apparently insensitive to changes in the distributional forms examined. Thus, based on the results presented, the estimation procedure is quite "robust."

William Dennis Lawing, Jr.: "Multiple Decision Sequential Procedures." Ph.D. thesis. Iowa State University Library. February 1965.

A general class of sequential procedures is given for choosing one of k simple alternative hypotheses concerning the parameter θ of a family of probability distributions of Koopman-Pitman type, i.e., a family with probability density function or discrete probability function of the form:

$$f(x;\theta) = \exp\,[U(x) + a(\theta)T(x) + b(\theta)].$$

Such a procedure is represented geometrically as a sequence of k-1 stages with each stage being terminated by the sample path crossing one of a pair of intersecting lines, forming a wedge, in the (m, T_m)-plane; here m is the sample size and $T_m = \sum_{j=1}^{m} T(x_j)$. Rules for assigning decisions to the successive crossings of boundaries are given.

The useful concept of parametric conjugacy is applied to the Koopman-Pitman class. A pair (θ_1, θ_0) are conjugate with respect to a line $T = h + sm$ in the (m, T_m)-plane if $c(\theta_1) = c(\theta_0)$, where $c(\theta) \equiv sa(\theta) + b(\theta)$. For a sample path terminating on (near) a line $T = h + sm$ and a pair (θ_1, θ_0) conjugate with respect to this line the ratio of the likelihoods on the path under θ_1 and θ_0 equals (approxi-

mately equals) exp $[h[a(\theta_1)-a(\theta_0)]]$. These likelihood considerations lead to the computation of OC functions for certain symmetric versions of the proposed k-decision procedure; in the binomial and normal (Wiener process) case, the OC functions are found on a grid of points (or lines, in higher dimensions) of parameter space. The Wiener process OC computations in fact give absorption probabilities for certain symmetric boundaries; for example equilateral triangle boundaries in two dimensions and cubes in higher dimensions.

Bounds and asymptotic behavior of the OC functions are found for the Wiener process, in the nonsymmetric case; these yield a characterization of the ordinary SPRT as the k-decision procedure satisfying a certain asymptotic optimality condition.

Angel Martinez: "Some Considerations on the Combined Analysis of Experiments." M.S. thesis. Iowa State University Library. May 1965.

The combined analysis of groups of experiments with some common treatments is discussed in this thesis. The model considered is a cross classification of treatments and sources of experimental material, e.g., places, and blocks nested within sources with unequal numbers.

Two types of treatments are distinguished; namely, common treatments and regular treatments. A treatment appearing in every experiment is a common treatment; otherwise, a regular treatment is obtained. It is noted that in the case of a group of p.b.i.b. designs, the combined estimator of a common treatment, in general cannot be expressed as a linear function of the individual estimators of the same common treatment. However, for the case of a group of randomized complete block or b.i.b. designs, it is shown that the combined estimator of a common treatment, under an appropriate linear constraint, can be given as the simple arithmetic mean of the individual estimators.

The approach used to obtain solutions of the reduced normal equations is different from other authors in that the estimator of a regular treatment is obtained by using a simple algebraic argument. The resulting estimator of a regular treatment equals the average of the individual estimators, under the usual constraint, i.e., $\sum_k \hat{\tau}_k = 0$, plus a correction term that depends upon the estimates of common treatment (it is noted that this result holds also for p.b.i.b. designs). The results given by Gomes and Guimarães (Biometrics, 1958) and Pavate (Biometrics, 1961) are obtained as particular cases of the above approach. Examples are given.

The analysis of perennial crop experiments is also discussed. Extensions of the split plot principal are given when incomplete block designs are used. The multivariate approach is described for completeness and an example of a duplicated 4×4 simple lattice design is presented.

Richard W. Mensing: "Reflection in the Plane." M.S. thesis. Iowa State University Library. February 1965.

The problem of this thesis is that of computing, for certain cases, the number of paths starting at a point U, ending at another point V, and either touching or crossing a certain boundary in the plane, with U and V located within the boundary. Counting is done by considering auxiliary paths starting at U and ending at points symmetric to V with respect to a certain auxiliary grid. By defining a reflection operation on these auxiliary paths, a 1-1 correspondence is established between paths touching or crossing the boundary and subsets of the auxiliary paths, much as is done in the case of the line.

Some boundary and step type systems considered are (i) square or rhombus boundaries with unit horizontal and vertical steps, (ii) isosceles right triangle boundary with unit horizontal and vertical steps, and (iii) equilateral triangle boundary with steps parallel to the sides of the boundary.

It is also pointed out that, such systems once solved, similar systems, generated from these by linear transformations or cartesian products, then are solved as well.

Fred Lawrence Ramsey: "Effect of Trend Elimination on Tests for Time Series." Ph.D. thesis. Iowa State University Library. August 1964.

A particular type of non-stationarity in stochastic processes has been investigated in this research. The observed process is assumed to be the sum of a linear regression function satisfying certain regularity conditions and a stationary residual which is a linear autoregressive scheme.

Three procedures are available for estimating the regression and autoregressive parameters: (i) the usual two-stage least squares procedure, (ii) Durbin's procedure, and (iii) the non-linear "full information" procedure. When the regression is trigonometric or polynomial, these three methods yield estimators which are all asymptotically efficient.

Therefore a comparison of these methods of estimation has been based on the sampling properties of the estimators when the sample size is "small." Asymptotic expansions have been derived for the estimators, from which expressions for the bias and covariances of the estimators have been obtained to order $1/n$.

Sampling properties of the goodness-of-fit tests for linear autoregressive schemes due to Bartlett and Diananda and to Quenouille have been investigated in the case when a trend is present. The first two moments of the test criteria have been calculated to order k/n, where k is the number of degrees of freedom associated with the asymptotic chi-square distribution.

These moments have been calculated for the appropriate test statistics when the hypothesis is simple, in the sense that the autoregressive parameters and the variance of the residuals are known, and when the hypothesis is composite, in the sense that some or all of these parameters are unknown.

On the basis of the bias and covariances to order $1/n$, it has been shown that there are no differences in the small sample properties of the estimators for

the three estimation procedures. Therefore, for composite hypothesis, unknown parameters in the test statistics have been replaced by their two-stage least squares estimators, as these are the simplest to obtain.

The effect of trend elimination on the moments, to order k/n, of the test statistics has been shown to be quite large, especially for polynomial trends. Thus in small samples, the conventional (asymptotic) significance levels may seriously overestimate or underestimate the true significance levels of the tests.

Thomas Dean Roseberry: "The Utilization of Concomitant Information in Sequential Procedures for the Comparison of Two Treatments." Ph.D. thesis. Iowa State University Library. February 1965.

The problem of utilizing measured concomitant information in sequential trials for comparing two treatments (e.g., two drugs, two diets, two operative techniques, etc.) is studied. Successive subjects are paired, each member of each pair being randomly allocated to one of the two treatments.

The analysis is based upon the treatment 1 minus treatment 2 response differences $y = y_1 - y_2$ and the corresponding concomitant observation differences $x = x_1 - x_2$, where x and y are assumed to follow the bivariate normal distribution with parameters $\mu_y = \mu$, $\mu_x = 0$, σ_x^2, σ_y^2 correlation coefficient ρ. Alternatively it is seen that the problem is that of sequentially testing hypotheses about the mean of a normal variable y when a normally distributed variable x, having mean zero and which is correlated with y, may be observed.

Sequential procedures have been developed for two basic formulations of the test hypotheses. Formulation 1 is H_T: $\mu = \mu_T$ versus H_A: $\mu = \mu_A$ and formulation 2 is H_T: $\mu = \mu_T$ versus H_A: $\mu = \mu_T + \gamma\sigma$. One- and two-sided alternatives for each of these basic formulations have been considered together with the modified formulation,

$$H_T\text{: } \mu \leq \mu_T \text{ versus } H_A\text{: } \mu \geq \mu_A \ (\mu_T < \mu_A).$$

The theoretical difficulty is that the test hypotheses are composite so that Wald's sequential probability ratio test (s.p.r.t.), which provides a satisfactory solution to the problem of testing simple hypotheses sequentially, is not directly applicable. The basic Wald framework has been made use of, however, in two approaches to the problem.

One approach taken is a large sample one in which the differences $\mu_T - \mu$ and $\mu_A - \mu$ are considered to be of order $n^{-\frac{1}{2}}$; it is shown that the resulting test in which nuisance parameters are replaced by their maximum likelihood estimators is asymptotically equivalent to the s.p.r.t. (in which these parameters are known). Large-sample test procedures are given for testing one- and two-sided alternatives for formulation 1. Some Monte Carlo experience with these procedures is presented.

A second approach is based upon the Wald weight-function technique. Weight-function procedures are developed for testing one- and two-sided alternatives for formulations 1 and 2 and for the modification of formulation 1. Numerical illustrations are given.

Martin Stephen Rosenzweig: "Regression Estimation for a Rotation Design." M.S. thesis. Iowa State University Library. August 1964.

A regression estimator for a rotation sample of N units enumerated on P occasions is derived. The estimator is

$$\bar{x}_R = \bar{x} - B\bar{z}$$

where $\bar{x}_R$ is the vector of means for each of the P occasions, B is the matrix of regression coefficients, $\bar{x}$ is the vector of untransformed sample means, and $\bar{z}$ is the vector of sample means which estimate a zero population value (constructed by taking differences among the x's). The least squares B is found, and the estimator becomes

$$\bar{x}_R = \bar{x} - \Sigma_{12}\Sigma_{22}^{-1}$$

with

$$E(\bar{x}_R\bar{x}_R') = \Sigma_{11} - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}.$$

The estimator is generalized to include auxiliary information which is (a) available on each member of the sample, and (b) constant over the period of the survey.

Using data from rural places in Webster County, Iowa, the mean for each occasion is estimated, and its covariance matrix is presented. For these data, use of the rotation estimator including auxiliary information (income) led to a maximum gain in precision of 24 percent.

Nangnoi Suwanphant: "Statistical Investigation on the Linear Relationships of Selected Factors Related to Internal Migration." M.S. thesis. Iowa State University Library. November 1964.

This thesis compared two theories of migration on how well each theory fit population change of small Iowa towns. The basic data were the populations of each town in 1950 and 1960 and the distance between each town and every other town within a 50-mile radius.

One theory proposed that the effect of one town on a particular target town depended on a complex relationship between the relative size of the two towns and the distance between them. That is, two small towns close together tended to inhibit each other's growth, whereas a large town near a small town tended to facilitate the small town's growth.

The other theory suggests that it is not the population of the two towns that determines out-migration from one to the other, but the "resistance" brought about by the population density in the area between the two towns.

Since the first theory took account of the "attraction" between any two towns and the second theory took account of the "resistance" encountered between any two towns, it was hypothesized that a model including both resistance and attraction might fit the data better than either alone.

Indices were derived from both theories and it was assumed that these indices would be related to population change linearly so that the linear regression

model was used. It was found that the attraction model accounted for about 12 percent of the total variance in population change and the resistance model added little to this.

Phrensi Svasti-Salee: "Statistical Design of Ohio Wildlife Survey, 1963." M.S. thesis. Iowa State University Library. February 1965.

This study is the third farmer attitude survey done by the Division of Wildlife, Department of Natural Resources, Ohio. These surveys were conducted in 1951, 1958 and 1963. The Statistical Laboratory of Iowa State University designed the sampling plan and analyzed the data for the first and third surveys.

The Ohio Wildlife Division was attempting to discover the ideas and opinions of the rural land-owning group, which controls a high percentage of Ohio's outdoor recreational opportunity, in order to plan better future programs and policies which involve rural land.

This study covers principally the Ohio farmers' attitudes toward hunting in 1963. The findings are based on a sample survey of 957 farmers who have ten or more acres in place in 1962. This group was randomly selected from the population of farmers residing in the open country zone of Ohio.

The sampling method used is a stratified random area sample in which counties serve as strata. There were 88 strata and 300 sample segments. The location of area segments to the different strata was made in proportion to the stratum size in terms of the estimated number of 1963 open country farms 10 acres and over. Master sample materials and county highway maps were used in locating the sample segments which were drawn systematically within each stratum.

For the purposes of the estimation, the whole state was considered as made up of the six wildlife districts (administrative divisions) and the differences between counties within a wildlife district were not taken into account. The ratio to size estimate was used for estimating the population total for each characteristic.

Richard William Swanson: "An Approximate Analysis of Variance Test for Testing Homogeneity of Binomial Samples." M.S. thesis. Iowa State University Library. November 1964.

In this thesis two methods are used to find the null sampling distribution of F_o to order n_i^{-1} $(1 \leq i \leq k)$ where F_o is the ratio of the between samples mean square and the within samples mean square, k is the number of samples and the variate is binomially distributed.

For the first method it had been intended to use Esseen's expansion in finding the sample distribution of F_o to order n_i^{-1} $(1 \leq i \leq k)$. However, this expansion was too difficult to handle and it was necessary to fall back on the standard Edgeworth expansion. This expansion was not a correct one to use since the Edgeworth expansion is valid only for distributions with a continuous component. It is hoped that the error involved in using this expansion rather than a more appropriate expansion such as Esseen's is small.

For the second method a certain randomization was used in order to obtain a continuous random variable in place of the discrete binomial variate. F_o was then defined in terms of the continuous variate and the Edgeworth expansion was used which is now appropriate in finding the sampling distribution of F_o to order n_i^{-1} $(1 \leq i \leq k)$.

The results obtained for both methods were quite similar.

Florence Gertrude Tetreault: "A Statistical Outlier Methodology for Observed Points and Lines." Ph.D. thesis. Iowa State University Library. May 1965.

The general purpose in making outlier tests depends upon the aim of the experiment. The aim may be (1) to identify possible outliers either as an end in itself or in order to investigate the conditions which may have led to this outlying observation; (2) to estimate population parameters or to test hypotheses.

If the latter is the aim of the experiment, then the outlier test is made to determine which sample values should be used to make these subsequent population inferences. This outlier test should be taken into account when making these inferences.

This thesis represents the first attempt to obtain a statistical outlier methodology when (2) is the aim of the experiment. We consider the problems of estimation and hypothesis testing subsequent to a preliminary test for a univariate statistical outlier. We investigate these problems (a) when the scientist has performed the preliminary test for an outlying observation assuming no a priori information, and (b) when the scientist has performed the preliminary test for an outlying observation assuming a priori information sufficient to identify a suspected outlier.

In both situations we simplify the problem by considering only the case where one observation is suspect. Formulae for the bias, mean square error and power are derived and some numerical values are obtained.

We also consider the problem of constructing an outlier methodology for straight lines. We term a line, $y = a + bx$, an outlier line if one of the following situations occurs: (i) the slope b is an outlier, whatever the intercept, (ii) the intercept a is an outlier, whatever the slope, (iii) the line, considered in its entirety, is an outlier.

Several approximate and hindsight test criteria are proposed. No attempt is made to study the power of these proposed test criteria.

James Raymond Veale: "A Procedure for the Estimation of a Mean from a Sample in which One Observation May Be Spurious." M.S. thesis. Iowa State University Library. May 1965.

When one member of a set of replications has a numerical value that is considerably larger (or smaller) than the other members of the set, one is tempted to reject it as spurious, i.e., affected by a gross error.

A procedure is presented for the estimation of a mean when one spurious datum is assumed. More precisely, it is assumed that the spurious datum is a random observation from $N(\mu + b\sigma, \sigma^2)$, and the other n—1 observations are independently chosen from $N(\mu,\sigma^2)$. The common variance σ^2 is assumed known and μ is to be estimated. An estimator is presented and attention is focused on its mean square error. The procedure advanced is a weighted estimator which generalizes the sometimes pool estimator, i.e., the rejection rule put forward by Anscombe.

A weighted estimator is defined in terms of a weighting function ψ. The weighting function and an estimator for the weighting function are derived so that the mean square error of the weighted estimator is minimized. The estimator, ψ_1, is dependent only on the largest (absolute) deviation and is such that $0 \leq \psi_1 \leq 1$. In the derivation the assumption is made that the observation with the largest (absolute) residual is, in fact, the spurious datum. This assumption is probable when b is fairly large.

The bias and mean square error of the weighted estimator are then derived under the same assumptions. The values of the bias and mean square error of varying b and n are presented in tabular form. The efficiencies of the weighted estimator relative to the sometimes pool, always pool and never pool cases are then presented graphically.

Ing-Tzer Wey: "Application of A Priori Information to the Estimation of Parameters in a Linear Regression Model." M.S. thesis. Iowa State University Library. May 1965.

Methods of incorporating *a priori* information about the coefficients of a linear regression model into the estimation procedure are investigated in this thesis.

These include estimation of parameters subject to exact linear restrictions, subject to a system of linear relations restricted by inequality constraints and for which "outside" information subject to errors is available, is considered.

An estimate of a linear regression coefficient β_i subject to the restrictions $B_L \leq \beta_i \leq B_U$, where B_L and B_U are known constants obtained from *a priori* information, is in general biased. Only if the bounds B_L and B_U are placed symmetrically with respect to β_i, will the estimator be unbiased. However the estimator has a lower mean-square error than the unrestricted estimator.

The construction of confidence intervals for parameter with a lower and an upper bound imposed, is considered as well as the testing of the null hypothesis H_o: $\beta_i = \beta_i^o$ against the alternative H_a: $\beta_i \neq \beta_i^o$, $B_L \leq \beta_i \leq B_U$. The power of this test is compared with that of the test having no bounds imposed on β_i. For every β_i^o in the interval $B_U - 1.96\text{S.E.}\ (\hat{\beta}_i) < \beta_i^o \leq B_U$, the power of the former test is greater than that of the latter test when $\beta_i < \beta_i^o$, and vice versa when $\beta_i > \beta_i^o$. And for every β_i^o in the interval $B_L + 1.96\text{S.E.}\ (\hat{\beta}_i) > \beta_i^o \geq B_L$, the power of the former test is greater than that of the latter test when $\beta_i > \beta_i^o$, and vice versa when $\beta_i < \beta_i^o$. Two tests are the same for every β_i^o in the interval $B_L + 1.96\text{S.E.}\ (\hat{\beta}_i) \leq \beta_i^o \leq B_U - 1.96\text{S.E.}\ (\hat{\beta}_i)$ and therefore have equal power in this interval.

The mixed multiple regression model is employed in the estimation of the parameters of the retail demand for all foods consumed in the United States during the period 1950-1962.

PAPERS AND SPEECHES

Papers presented at scientific and professional meetings reflect the research and activities of the Statistical Laboratory staff. Many of these papers will appear later in publications. Abstracts of papers are often published, and in such cases references are given.

T. A. Bancroft: "A Statistical Inference Theory for Incompletely Specified Models," at the meeting of the Institute of Mathematical Statistics, University of Massachusetts, Amherst, August 26-29.

Foster B. Cady: "Design and Analysis of Rotation Experiments," at the Iowa Section of the Agronomy Society of America, Ames, January 18.

Foster B. Cady: "Statistical Implications in Interpretation of Data," at the Plant Pathology Seminar, Iowa State University, Ames, February 9.

Herbert T. David: "What Is Statistics" and other lectures, given as visiting lecturer in statistics at Fort Hays State College, Hays, Kansas, November 9; Monmouth College, Monmouth, Illinois, January 20-21; University of South Dakota, Vermillion, March 16-17.

H. T. David and **Carol E. Fuchs**: "Poisson Limits of Multivariate Configuration Distributions," at joint meetings of the American Statistical Association, Biometric Society (ENAR) and (WNAR) and the Institute of Mathematical Statistics (Central Region) in Chicago, Illinois, December 27-30.

A. H. El Mawaziny and R. J. Buehler: "Confidence Limits for the Reliability of a Series System (Preliminary Report)," at joint meetings of the American Statistical Association, Biometric Society (ENAR) and (WNAR) and the Institute of Mathematical Statistics (Central Region) in Chicago, Illinois, December 27-30. Abstract 15 in Annals of Mathematical Statistics, 36:1, 353, February 1965.

Donald K. Hotchkiss: "Statistical Evaluation of Palatability Feeding Trials," at the Iowa Feed and Nutrition Seminar, Ames, May 20.

B. K. Kale: "Approximations to the Maximum Likelihood Estimator Using Grouped Data," at the spring regional meeting of the Institute of Mathematical Statistics (Eastern Region), Biometric Society (ENAR) and American Statistical Association (Biometrics Section and Section on Physical and Engineering Sciences) in Tallahassee, Florida, April 29-May 1. Abstract 8 in Annals of Mathematical Statistics, 36:2, April 1965.

O. Kempthorne: "The Current Status of the Design and Analysis of Experiments," at the meeting of the Institute of Mathematical Statistics, University of Massachusetts, Amherst, August 26-29.

O. Kempthorne: "Development of the Design of Experiments Over the Past Ten Years," at a conference on the Design of Experiments in Army Research, Development and Testing, in Washington, D. C., November 4.

O. Kempthorne: "Randomized Experiments with Multivariate Responses," at the International Symposium on Multivariate Analysis, University of Dayton, Dayton, Ohio, June 14-19.

Akio Kudô: "An Optimum Solution of a Three-Decision Problem Involving Classification," at the central regional meeting of the Institute of Mathematical Statistics in Lincoln, Nebraska, April 1-3. Abstract 5 in Annals of Mathematical Statistics, 36:2, 727, April 1965.

Akio Kudô: "On Sequential Multinomial Estimation," at the spring regional meeting of the Institute of Mathematical Statistics (Eastern Region), Biometric Society (ENAR) and American Statistical Association (Biometrics Section and Section of Physical and Engineering Sciences) in Tallahassee, Florida, April 29-May 1. Abstract 9 in Annals of Mathematical Statistics, 36:2, April 1965.

Akio Kudô: "Tests with Restricted Alternative Hypotheses in Multivariate Analysis," at a Department of Statistics seminar, Michigan State University, East Lansing, May 25.

Akio Kudô: "On Some Statistical Aspects of a Human Genetics Survey Conducted in Fukuoka City," at a Department of Human Genetics seminar at the University of Michigan, Ann Arbor, May 27.

Akio Kudô: "Some Multivariate Tests with Restricted Alternative Hypothesis," at the International Symposium on Multivariate Analysis, University of Dayton, Dayton, Ohio, June 14-19.

W. D. Lawing, Jr. and **H. T. David**: "Multi-Decision Sequential Procedures (Preliminary Report)," at the meeting of the Institute of Mathematical Statistics, University of Massachusetts, Amherst, August 26-29.

Joseph Sedransk: "An Application of Sequential Sampling to Analytical Surveys," at joint meetings of the American Statistical Association, Biometric Society (ENAR) and (WNAR) and the Institute of Mathematical Statistics (Central Region) in Chicago, Illinois, December 27-30. Abstract 1089 in Biometrics, 21:1, 256-257, March 1965.

David R. Thomas and **H. T. David**: "Asymptotic Value Distributions for Certain k x n Games and n-Stage Games of Perfect Information," at the central regional meeting of the Institute of Mathematical Statistics in Lincoln, Nebraska, April 1-3.

Richard Warren and William F. Kenkel: "Measurement of Goal Agreements Between Husbands and Wives," at the annual meeting of the Midwest Sociological Society in Minneapolis, Minnesota, April 22-24.

C. J. Cranny, A. C. Mackinney and **Leroy Wolins**: "Improvement in Validity and Reliability Through Application of Continuous Confidence Responses to Aptitude Test Items," at the meeting of the Midwestern Psychological Association in Chicago, Illinois, April 29-May 1.

PARTICIPATION IN PROFESSIONAL ACTIVITIES

Dr. Om P. Aggarwal has served during the year as a referee for the Annals of Mathematical Statistics.

Dr. Aggarwal chaired the session on Contributed Papers I of the Social Statistics Section of the American Statistical Association at joint meetings of the ASA, Biometric Society (ENAR) and (WNAR) and the Institute of Mathematical Statistics (Central Region) in Chicago, Illinois, December 27-30.

At the same joint meetings, Dr. T. A. Bancroft presided at meetings of the Eastern North American Region, Biometric Society. He concluded his term as president of the Biometric Society (ENAR) in January.

Dr. Bancroft was appointed a member of the National Research Council to represent the Biometric Society (ENAR) in the Division of Biology and Agriculture of the National Academy of Sciences. He will serve until July 1967.

D. J. Finney, president of the Biometric Society, appointed Dr. Bancroft organizer for the International Symposium on "Biometry and Statistics in Food, Population and Health Research." The symposium will be sponsored by the Biometric Society in Mexico City in 1966. Dr. Om P. Aggarwal is one of three organizing secretaries working on the organization of the meeting.

Dr. Bancroft also was appointed a member of the Advisory Committee on Statistical Policy, established by the American Statistical Association, to consult with the Office of Statistical Standards, Bureau of the Budget. He continues as a member of the ASA Board of Directors.

At the University of Massachusetts, August 26-29, Dr. Bancroft served on the program committee and chaired a session at the meeting of the Institute of Mathematical Statistics. He also was a member of the IMS program committee at the spring regional meeting of IMS (Eastern Region)), the Biometric Society (ENAR) and the American Statistical Association (Biometrics Section and Section on Physical and Engineering Sciences) which met in Tallahassee, Florida, April 29-May 1.

In January Dr. Bancroft was asked to serve on a special committee of the Institute of Mathematical Statistics to develop and report on methods universities may use to initiate or develop statistical programs in teaching and research. It is planned that IMS will make the committee's recommendations available to universities or consortiums of universities which are planning to develop statistical programs.

Dr. Foster B. Cady represented the Biometric Society (ENAR) in discussing the proposed International Biological Program and served on the program committee at joint meetings of the American Institute of Biological Scientists and the Biometric Society (ENAR) and (WNAR) at the University of Colorado August 25-26. Dr. Cady continues as a member of the regional committee of the Biometric Society (ENAR).

In December Dr. Cady was re-elected secretary of the Biometric Section of the American Statistical Association, to serve until January 1966.

At the Plant Breeding Symposium held at Iowa State March 1-5, Dr. Cady chaired a panel on "Significance of Experimental Design in Plant Breeding."

Professor C. Philip Cox was named a member of the regional advisory board of the Biometric Society (ENAR).

Professor Cox was invited to lecture at Yale University at the 1965 Summer Session of Statistics in the Health Sciences, which began June 28.

Dr. Herbert T. David was one of 30 members named a Fellow of the American Statistical Association at the ASA Chicago meetings in December. He was honored "for his contributions in statistical theory and methodology in engineering and industrial statistics, particularly for his research in sequential analysis and nonparametric inference."

Dr. David was re-appointed a visiting lecturer in

statistics under the auspices of the National Science Foundation and the Biometric Society, American Statistical Association and the Institute of Mathematical Statistics. He has been appointed a member of the directing committee for the 1965-1966 visiting lecturer program.

During the year Dr. David has served as a referee for the Annals of Mathematical Statistics, Biometrika and the Journal of the American Statistical Association.

Five staff members serve as editorial collaborators for the Journal of the American Statistical Association. They are: Dr. Om P. Aggarwal, Dr. T. A. Bancroft, Dr. William Hemmerle, Dr. Oscar Kempthorne and Dr. George Zyskind.

Dr. David Huntsberger was elected president of the Iowa Chapter of the American Statistical Association. The newly-elected secretary of the chapter is Dr. Carol E. Fuchs.

Dr. Huntsberger served as a member of the Executive Council of Sigma Xi during 1964-65.

In November Dr. Huntsberger was notified that his book, *Elements of Statistical Inference*, had been selected by the U. S. Armed Forces Institute as one of the texts most representative of the typical course in Basic Statistics.

Dr. B. K. Kale and Dr. Edward Pollak were invited to attend the Fifth Berkeley Symposium on Mathematical Statistics and Probability at the University of California, Berkeley, beginning June 21. They participated under funds provided by the National Science Foundation.

During the year Dr. Kale has continued to serve as a reviewer for the Journal "Zentralblatt für Mathematik."

Dr. Oscar Kempthorne has been appointed a member of the U. S. Committee for Planning the International Biological Program.

Dr. Kempthorne also has been named a council member of the Biometric Society, representing the Eastern North American Region. He will serve a two-year term, 1965-1967.

During 1964 Dr. Kempthorne served as an editorial associate for Biometrics.

Dr. George Zyskind concluded his term as a member of the council of the American Statistical Association.

During the year several staff members have been active on various Iowa State committees:

Dr. T. A. Bancroft served on the College of Sciences and Humanities Cabinet Committee on Alumni and Faculty Awards.

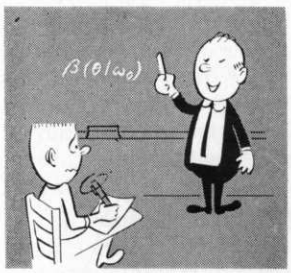
Dr. Foster Cady served as a member of the Faculty Council.

Dr. H. T. David has been on the Annuities and Insurance Committee and has served as a member of the Graduate Study Committee and as chairman of its Physical Sciences Subcommittee.

In April Dr. David was elected to the Academic Standards Committee of the College of Sciences and Humanities for a four-year term.

Dr. D. V. Huntsberger served as a member of the Advisory Committee on Teacher Education and a member of the Teacher Education Faculty for 1964-65. He has been elected to the Nominating Committee of the College of Sciences and Humanities for a three-year term. In December he was appointed to the Committee on Fellowships of the Graduate College.

Teaching



The Department of Statistics in the College of Sciences and Humanities at Iowa State offers work leading to the degrees of bachelor of science, master of science, and doctor of philosophy with majors in statistics. Each major is built around a common core of courses in theory and methods, with other courses chosen to fit the individual student's background and interests. At all levels, the program in statistics is designed to emphasize the close relationship between sound application and modern statistical theory.

The department also offers minor and supporting work in statistics. When desired, a joint major program may be arranged between statistics and agriculture, biology, economics, engineering, genetics, mathematics or psychology. During the year the State Board of Regents approved the establishment of an interdisciplinary program in computer science, under the departments of statistics, mathematics and electrical engineering. As of July 1, 1965, students may enroll in an M.S. or Ph.D. program in computer science, or in computer science joint with statistics.

With the completion of third floor remodeling, training facilities include three student laboratories equipped with nearly 100 electric calculating machines for course instruction and for student use during nonclass hours. Use is also made of the IBM 7074-1401 high speed computer and electrical equipment for punch card analysis of data which are located in the university's Computation Center.

The Statistical Laboratory library includes reprints of articles considered important in theoretical and applied statistics, reprints of staff publications, graduate theses, various statistical journals, reference books and other publications obtained on an exchange, gift or loan basis.

The Department of Statistics continues to grow as

the use of statistics increases in all branches of learning, and changes are made in the curriculum as necessary to keep pace with the needs of the students.

There has been a sharply increased enrollment in the two-year-old additions to the Principles of Statistics sequence. Enrollment in 201A, for students in agricultural and biological sciences, has nearly doubled in the past year, while 201B, for students in engineering, has an enrollment nearly three times as high as the previous year.

Demand for 621, Advanced Design of Surveys, prompted the offering of it in 1965, although it usually is offered only in even years. Enrollment was considerably higher than in 1964.

A new Special Topics course at the graduate level, offered for the first time in spring quarter, began with an enrollment of 15. It's 599X, Decision Theory.

COURSE OFFERINGS IN STATISTICS

The courses offered by the Department of Statistics during the academic year 1964-65 were as follows:

Courses for Undergraduate Students Only

201,	Principles of Statistics	5	FWS*	DeGracie, Fuchs, Hall, Huntsberger, Lund, Veale
201A,		3	WS	Cady, Hotchkiss, Huntsberger
201B		3	FS	Lawing, Mensing
327	Elementary Business Statistics	3	F	Fuchs
341,	Introduction to Theory of	3	F	Huntsberger
342	Probability and Statistics	3	W	Huntsberger
380	Introduction to High Speed Computing	3	FWS	Jespersen, Soults

Courses for Graduate Minors and Undergraduates

401,	Statistical Methods for Research Workers	4	FW, SS_1	Burmeister, Cady, Cox, DeGracie, Fuchs, Hotchkiss, Lawing, Lund, Prescott, Shih, Warren, Wolins
402		4	SS_2, WS	Cady, DeGracie, Fuchs, Lawing, Warren, Wolins
411	Experimental Design for Research Workers	3	S, SS_1	Cady, Hotchkiss
421	Survey Design for Research Workers	3	SS_2, S	Fuller, Sedransk
431	Elementary Statistical Quality Control	3	S	Carney
446,	Statistical Theory	3	F	Hotchkiss
447,	for	3	W, SS_1	Fuchs,
448	Research Workers	3	SS_2, S	Huntsberger Huntsberger
480,	Processing of	2	F	Mosier
481,	Statistical	2	W	Mosier
482	Data	2	S	Mosier
499	Special Problems	Arr.	SS_2, FWS, SS_1	Aggarwal, Fuchs, Hotchkiss, Huntsberger, Soults

Courses Primarily for Graduate Students, Major and Minor

501	Intermediate Statistical Methods	3	F	Bancroft
505	Psychometrics	3	S	Wolins
506	Factor Analysis	3	F	Wolins
511,	Design of	3	W	Kempthorne
512	Experiments	3	S	Zyskind
521,	Design of	3	W	Sedransk
522	Surveys	3	S	Sedransk
531	Industrial Statistics: Sampling Inspection	3	F	David
535	Biological Statistics	3	S	Cox
536,	Genetic	3	F	Pollak
537	Statistics	3	W	Pollak
538	Elementary Econometric Statistics	3	SS_2, F	Fuller, Ladd
539	Operational Research Methods	3	W	David
541,	Theory of Probability	3	F	Kale
542,	and	3	W	Kale
543	Statistics	3	S	Kale
580,	Scientific Applications of	3	W	Hemmerle
581	Digital Computers	3	S	Hemmerle
599	Special Topics	Arr.	FWS, SS_1	
	A. Theory			Kempthorne
	B. Methods			Cox, Fuchs, Hotchkiss, Soults
	C. Design of Experiments			Aggarwal, Cady
	D. Design of Surveys			Sedransk
	X. Decision Theory			David

Courses for Graduate Students, Major and Minor

601	Advanced Statistical Methods	3	F	Cox
611,	Advanced Design of	3	W	Zyskind
612	Experiments	3	S	Kempthorne
621	Advanced Design of Surveys	3	W	Aggarwal
622	Seminar on Design of Surveys	3	S	Aggarwal
641	General Theory of Linear Hypothesis	3	F	Zyskind
642	Probability and Distribution Theory	3	F	Ramsey
643	Theory of Estimation and Testing of Hypotheses	3	W	Kudô
647	Multivariate Analysis	3	S	Kudô
649	Recent Developments in Statistics and Probability	3	SS_1	Kudô
699	Research	Arr.	SS_2, FWS, SS_1	Aggarwal, Bancroft, Cady, Chanda, Cox, David, Hemmerle, Huntsberger, Kempthorne, Zyskind

*Because the fiscal year began July 1, 1964, and ended June 30, 1965, the courses taught in the second summer session of 1964 through the first summer session of 1965 are reported here. Symbols indicate the quarter each course was taught: SS_2-Second Summer Session, F-Fall, W-Winter, S-Spring, SS_1-First Summer Session.

Survey Sampling Institute

From left, row 1: Eugene Clubine, Ernest Johnson, Om P. Aggarwal, N. V. Strand, P. V. Sukhatme, T. A. Bancroft, Carl Kossack; row 2: Duangchai Thavisin, Marlan Sastrowikromo, Helen Ayres, Thomas Jetton, Margaret Liston, J. E. Hamelberg; row 3: Kedar Acharya, Baldwin Banks, N. Amerkhail, K. B. E. Quagrainie, Hazel Cook, Sunee Uneklabh, Isaac Randolph; row 4: Francis Clinton, Abel Massalee, A. B. Harmon, Abas Jusuf, Bulent Ersoy, Emanuel Gardiner, Ho-Fu Chi.

INSTITUTES AND SHORT COURSES

In addition to regular course offerings, special short term institutes are offered for campus and off-campus personnel.

Summer Institute on Survey Sampling Techniques

Seventeen foreign students were on campus during the second summer session, July 20-August 28, for a special summer institute on survey sampling techniques under an arrangement with the United States Bureau of the Census. Eleven participants were sponsored by the Agency for International Development and six by the United Nations.

The program was planned to train participants to return to responsible positions in statistics in their own countries. They came from Afghanistan, Ghana, Indonesia, Jordon, Liberia, Nepal, Pakistan, Taiwan, Thailand and Turkey.

The responsibility for the administration of the institute was shared by Dr. T. A. Bancroft and Dr. Calvert L. Dedrick, Chief of International Statistical Programs, Bureau of the Census. Ernest Johnson, a member of Dedrick's staff, was in Ames to assist with the project.

Participants spent most of their time working on a demonstration survey program conducted by Dr. Om P. Aggarwal, Professor N. V. Strand and personnel of the Survey Group. They planned a survey, drew a sample, wrote a questionnaire, studied interviewing techniques, collected, edited, code punched and verified data, examined tabulated material and wrote a report.

The course included lectures on consumption economics by Dr. Margaret Liston, Head of the Department of Home Management, and an elementary course in sampling statistics taught by Dr. Aggarwal and Dr. Joseph Sedransk. Two special guest lectures were given: Dr. P. V. Sukhatme, Director of the Statistics Division, Food and Agricultural Organization of the United Nations, spoke on "Food and Population." Dr. Carl F. Kossack, Director of the Laboratory for Computer Sciences, Southwest Center for Advanced Studies, Dallas, Texas, discussed "The Design and Analysis of a Wage Survey." Both men are internationally known statisticians.

Computer Applications Short Course

The Numerical Analysis-Programming Group offered a special computer applications short course in four sessions during September and October for Iowa State staff members and graduate students.

The course was planned to apprise current or prospective computer users of the existing software available in the area; to provide a clearer understanding of the computational methods employed in systems and programs currently in use; and to instruct in the use of specific systems or programs.

Over 100 persons participated in the course which was directed by Dr. W. J. Hemmerle. Class work included the study of computing systems and programs for analysis of variance, regression, factor analysis, mathematical programming and other statistically oriented applications.

Statistical Laboratory personnel taking part on the program were, in addition to Dr. Hemmerle: T. A. Bancroft, James Blinn, Edward Carney, Mary Ann Carney, Ed Fuller, Howard Jespersen, John Meyer, James Prescott, Gretchen Snowden, Don Soults and David Thomas.

Engineering and Management Institute

Engineering Extension and the Department of Industrial Engineering, with the cooperation of the Statistical Laboratory, conducted an institute on design for quality control April 20 and 21. This was the fifth such cooperative effort in this area.

The major emphasis of the institute was an over-all look at quality control, its organization and relation to other functions. It was particularly designed for persons with responsibility for organizing and planning quality control, and for those wishing a wide perspective of the field.

E. J. Carney was chairman of the institute's planning committee and H. T. David was a committee member. Both participated in the institute. Carney directed a computer lab session in which participants attempted to control the quality of a process being simulated on the Cyclone computer. He discussed "Sampling by Variables" and Dr. David spoke on "Sequential Procedures in Quality Control."

GRADUATE STUDENTS

In addition to working with statistics majors, many Statistical Laboratory faculty members work closely with graduate students minoring in statistics. One indication of this work is the participation on graduate committees where the student has formally declared a minor in statistics at the Ph.D. level.

During the academic year, 12 professors served on 50 committees for students taking the written preliminary exam in statistics with majors in agricultural economics, agricultural engineering, agronomy, animal science, chemical engineering, economics, education, electrical engineering, fish and wildlife management, industrial engineering, mathematics, poultry science and sociology.

Professors who regularly serve on M.S. and Ph.D. committees in areas where the major is other than statistics include Bancroft, Cady, David, Fuller, Hotchkiss, Huntsberger, Kempthorne, Pollak and Wolins.

Sixteen staff members are members of the graduate faculty. Full members are: Dr. Aggarwal, Dr. Bancroft, Dr. Cady, Professor Cox, Dr. David, Dr. Fuller, Dr. Kempthorne, Dr. Wolins and Dr. Zyskind. Associate members are: Dr. Fuchs, Dr. Hemmerle, Dr. Huntsberger, Dr. Pollak and Dr. Sedransk. Dr. Kale and Dr. Kudô are honorary members of the graduate faculty.

There has been a 25 percent increase in the number of candidates for graduate degrees since last year's annual report:

Ph.D. Candidates

Rodney P. Basson
Edward J. Carney
Leroy Edward Carver
Patricia Conn
Charles Cress
James S. DeGracie
Thomas Doerfler
Ahmed El Mawaziny
James Gebert
Burwell Gooch
Lawrence Gould
Irving Hall
John Johnson
Dennis Lawing
Richard Lund
John Meyer
Esmat Nouri
Fred Ramsey
Thomas Roseberry
Donna J. Ruhl
Ahmed Salem
Charles Sampson
Chang-Sheng Shih
V. B. Solomon
Donald Soults
Florence Tetreault
David Thomas
Milton Weiss
Mia Mohammed Yusuf

M.S. Candidates

Mohammed Aslam
Joseph Atkinson
Geoffrey Boehm
James Blinn
Carlos Brain
Leon Burmeister
Ralph Folsom
Edmund Fuller
Amiri Gamshadzahi
Charles K. Graham
Paul A. Johnson
Shun-jong Lee
Mark Malone
Frank B. Martin
Angel Martinez
Richard Mensing
James Olin
Martin Rosenzweig
Carl Z. Roux
Nancy Blackford Rowe
John Schlater
Stephen Selvin
Jarilaos Stavrou
Nangnoi Suwanphant
Phrensi Svasti-Salee
Richard Swanson
James Veale
Ing-Tzer Wey
Hermann Wiedenhofer
Janet Zrubek

Degrees Granted and Positions Taken

During the academic year 1964-65, the number of students receiving advanced degrees increased 33⅓ percent over the previous year. Titles and abstracts of theses written as part of the requirements for advanced degrees appear in the research section of this report.

Recipients of the Ph.D. Degree

Fred Ramsey (August 1964, under K. C. Chanda) received a postdoctoral fellowship to Johns Hopkins University.

William Dennis Lawing (February 1965, under H. T. David) joined the staff of the Research Triangle Institute, Durham, North Carolina.

Tom Roseberry (February 1965, under C. Philip Cox) accepted a position with C-E-I-R Inc. at Dugway Proving Ground, Dugway, Utah.

Charles Cress (May 1965, joint major in statistics and plant breeding, under Oscar Kempthorne and Kenneth J. Frey) joined the Rutgers University Statistics Center as an assistant professor.

Florence Tetreault (May 1965, under T. A. Bancroft) remains on the staff at the University of Detroit.

Ahmed El Mawaziny (May 1965, under Robert Buehler) returned to Egypt.

Rodney Basson (May 1965, under George Zyskind) joined Atlas Chemical Industries, Wilmington, Delaware, as a biometrician.

Recipients of the M.S. Degree

Martin S. Rosenzweig (August 1964, under Wayne Fuller) remains at Iowa State, working toward his doctorate.

Nangnoi Suwanphant (November 1964, under Leroy Wolins) returned to Thailand where she is on the faculty of Chulalongkorn University.

Richard Swanson (November 1964, under K. C. Chanda) is now working as a statistician with the ARINC Research Corporation, Washington, D. C.

Ed Fuller (February 1965, under William Hemmerle) joined General Foods Corporation in White Plains, New York.

Richard Mensing (February 1965, under H. T. David) remains at Iowa State, working toward his doctorate.

Phrensi Svasti-Salee (February 1965, under Om P. Aggarwal) returned to Thailand where she is a staff member of the Central Statistical Office.

Angel G. Martinez (May 1965, under Foster Cady) returned to Mexico and his position with the Institute for the Improvement of Sugar Production.

James Veale (May 1965, under David Huntsberger) joined the staff of the University of Wyoming as an instructor.

Ing-Tzer Wey (May 1965, under Wayne Fuller) remains at Iowa State, working toward his doctorate.

The George W. Snedecor Award in Statistics

For the first time in the 12 years that the Snedecor Award has been made, two winners were named. Donna Jean Ruhl and David R. Thomas were selected by the graduate faculty in statistics as the department's most outstanding candidates for the Ph.D. degree.

Given annually in honor of Professor George W. Snedecor, the award consists of a year's membership in the Institute of Mathematical Statistics, a subscription to the Institute's Annals and a cash gift.

Winners' names are inscribed on a plaque which remains in the main office of the Statistical Laboratory.

UNDERGRADUATES

Dr. D. V. Huntsberger continues as undergraduate adviser with about 30 students under his direction each quarter. Ten students received B.S. degrees during the academic year, as compared with six B.S. graduates last year.

Recipients of the B.S. Degree

Bekele Teguene (August 1964)
John Hunt (November 1964)
Beryl Reckord (November 1964)
LeRoy Snyder (February 1965)
John Allen (May 1965)
John DeMarle (May 1965)
Mary Hanson (May 1965)
Terry Jenkins (May 1965)
Ronnie Mead (May 1965)
Steven Rickey (May 1965)

Iowa State University Stat Club

Undergraduate statistics majors continued their support of the Stat Club, with the assistance of faculty advisers Dr. Carol Fuchs and Dr. D. K. Hotchkiss.

Under the leadership of Terry Jenkins, president; John DeMarle, vice president; Ronnie Mead, secretary, and James Destival, treasurer, the club sponsored regular programs. Forecasting state elections was the topic of an October panel discussion by Professors T. A. Bancroft and W. J. Hemmerle and Robert Clyde, news manager of WOI AM-FM-TV.

In February, Professor Norman Strand and Harold Baker talked about the preparation of survey questionnaires, prior to the club's special project of collecting career information from all ISU statistics graduates. Professor D. V. Huntsberger reported on the results of the survey of graduates at the April meeting, and the information was used in the Veishea display.

Ronnie Mead was chairman of the Veishea Statistics Open House, which was awarded first place in the physical sciences division of the College of Sciences and Humanities. The display translated the information collected from the graduates into a graphic presentation of job opportunities for B.S. graduates in statistics, and demonstrated probability concepts in games of chance.

Officers elected to carry on club activities for 1965-66 are: Adele Berry, president; David Challed, vice president; Sue Manchester, secretary, and Sandy Thompson, treasurer.

SEMINARS

Statistical Laboratory-Department of Statistics Series

Each year the Statistical Laboratory and the Department of Statistics sponsor weekly seminars which are offered on a non-credit basis and are open to students and faculty from other departments on the campus. Talks on current staff and graduate research projects and on more general developments in particular areas of statistics precede informal discussion.

The seminar committee was composed of H. T. David, chairman; W. J. Hemmerle and Joseph Sedransk. The 1964-65 program included the following topics and speakers:

		Fall Quarter 1964
September	16	The Outlook for Statistics in '64-'65. T. A. Bancroft
September	23	Multi-Decision Sequential Procedures. W. D. Lawing
September	30	The Agricultural Census in Peru. Om P. Aggarwal
October	7	On the Survival of a Gene in a Subdivided Population. Edward Pollak
October	14	Estimation from a Truncated Exponential Family. B. K. Kale
October	21	(meeting of Iowa Chapter, American Statistical Association in Des Moines): Some Recent Topics in Actuarial Mathematics. C. J. Nesbitt, University of Michigan
October	28	Valid Experimental Error in Nutritional Experiments. D. K. Hotchkiss
November	6	(joint Statistical Laboratory and Department of Economics): ϕ - Distinguishability of Families of Distributions. H. S. Konijn, City College of New York
November	11	Some Developments in the Design of Experiments Over the Last Ten Years. Oscar Kempthorne
November	18	(joint Statistical Laboratory and Department of Mathematics): Transition from Discrete to Continuous Time in the Theory of Stationary Processes. Pesi Masani, Indiana University
		Winter Quarter 1965
December	8	(joint Statistical Laboratory and Department of Mathematics): The Convex Hull of a Random Set of Points, Bradley Efron, Stanford University
December	16	Robustness of the Maximum Likelihood Estimation Procedure in Factor Analysis. E. L. Fuller
January	13	Analysis of Psychological Experiments Over Time. Leroy Wolins
January	20	Reflection in the Plane. Richard Mensing
January	27	Symmetric Multiple Decision Problems. Akio Kudô
February	3	Using Order Statistics to Make k-Stage Tests of Certain Hypotheses. John E. Hewett, University of Iowa
February	10	A Large Sample Sequential Test, Using Concomitant Information for Discrimination Between Two Hypotheses. Philip Cox
February	18	(meeting of Iowa Chapter, American Statistical Association in Ames): Bayes' Theorem and Scientific Inference. C. H. Kraft, University of Minnesota
		Spring Quarter 1965
March	10	Allocation Problems in Multivariate and Multipurpose Surveys. Samprit Chatterjee, Harvard University
March	17	On the Invariance of a Class of Canonical Forms Arising in the Analysis of Experimental Structures. George Zyskind
March	24	Unbiased Estimators Employing Post Strata. Wayne A. Fuller
March	31	Less-Than-Certain Statistical Answers for Economists. George W. Ladd
April	7	Designing Surveys. Joseph Sedransk
April	12	Sampling With or Without Replacement? J. N. K. Rao, Graduate Research Center of the Southwest at Dallas

April	15	Fiducial Theory and Invariant Estimation. Robert Buehler, University of Minnesota
April	21	Imbedded Semi-Markov Processes in Queues. Marcel Neuts, Purdue University
April	27	(joint Statistical Laboratory and Department of Mathematics): Commutative Urn Scheme for Simple Learning on a Continuum. Barry G. Arnold, Stanford University
April	30	Inventory Models. Charles Boll, Washington University
May	5	Statistical Outlier Methodology for Observed Points and Lines. Florence Tetreault, University of Detroit
May	11	A Stochastic Theory for PERT Critical Path Analysis. H. O. Hartley, Texas A. and M. University
May	19	Sampling Designs in Forest Inventory. Kenneth D. Ware

Quantitative Genetics Series

Seminars are held regularly on topics in quantitative genetics. Staff members and graduate students participating are from the departments of statistics, genetics, animal science, poultry science, agronomy and horticulture. Professors Kempthorne and Pollak were in charge of arranging the series. The following seminars were given:

October	13	Decline in Fitness with Artificial Selection in Poultry. A. W. Nordskog
October	27	The Role of Population Subdivision and Migration in the Survival of a Mutant Gene. Edward Pollak
November	10	Problems in Maximizing Genetic Progress from Selection. L. N. Hazel
December	15	Markov Mating Systems. J. G. O'Mara
January	19	A Method for Calculating Inbreeding Coefficients. Akio Kudô
March	9	Population Potential Versus Host Synchronization. Ian M. Campbell
March	23	Some Effects of Fluctuating Offspring Distributions on the Survival of a Gene. Edward Pollak
May	20	Research in Dairy Cattle Breeding at the University of Minnesota. Charles W. Young, University of Minnesota

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Susan Alice Brown, editor